Special Protection Area Program Annual Report 2008

Prepared by the Montgomery County Department of Environmental Protection in Cooperation with the Department of Permitting Services and the Maryland-National Capital Park and Planning Commission

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Executive Summary

Introduction

The Special Protection Area (SPA) program was initiated in 1994 by County law. According to the Montgomery County Code, Section 19-61(h), a Special Protection Area is defined as:

> "a geographic area where:
> (1) existing water resources, or other environmental features directly relating to those water resources are of high quality or unusually sensitive; and
> (2) proposed land uses would threaten the quality or preservation of those resources or features in the absence of special water quality protection measures which are closely coordinated with appropriate land use controls."

SPA monitoring provides information to help evaluate: (1) the effectiveness of the SPA program in minimizing development-related impacts to sensitive streams; and, (2) the efficiency, performance, and effectiveness of best management practices (BMPs) in reducing pollutants. This Annual Report covers the 2008 monitoring year.

During 2008, stream conditions changed little in the SPAs. Out of 49 stations monitored, five stations had improved stream conditions from 2007. Forty-four stations (90%) had no change in stream conditions. Two stations in Clarksburg improved from *fair* to *good;* one station is within the lower Town Center Tributary and the other station is located within a tributary of Great Seneca Creek in Wildcat Branch. Two stations in the Piney Branch SPA improved from *poor* to *fair.* In the Upper Paint Branch SPA, one station improved from *fair* to *good*. Additional details of these changes are provided in the biological monitoring section of this Executive Summary and in the report.

Streams, by nature, are constantly changing and receiving continuous inputs from the air, the surrounding land surface, and underground. Impacts from these inputs are long term and cumulative. Instantaneous water chemistry data reflect conditions for a single point in time and are not indicators of the cumulative impacts to county streams. Monitoring of long term and cumulative stream conditions is needed over instantaneous snapshots. The County measures the degree of cumulative impacts to our streams through the monitoring of biological indicators, specifically the range and condition of benthic macroinvertebrates (bottom-dwelling aquatic insects, worms, crustaceans, and mollusks) and fish that are living in the stream. The compositions of these biological communities are ideal indicators of the health of a stream system. Biological monitoring does not measure water chemistry or specific pollutant loads.

BMP monitoring, on the other hand, typically includes flow-weighted sampling for the reduction of pollutant loads including sediment, nutrients, metals, and toxins. BMPs are defined as techniques that are effective in eliminating or reducing the amount of pollution or other detrimental impacts to a watershed or wetland (Montgomery County Code 19-61(a)). Ongoing monitoring of sediment and erosion control (S&EC) BMPs continues to provide data on total suspended solids (TSS) removal. Results from the monitoring of stormwater management (SWM) BMPs are also presented in this report. Preliminary results indicate that BMPs are performing well; in some cases they are performing better than expected. However, biological monitoring indicates varying degrees of degradation in the streams. The efficiencies of the BMPs are not correlating to the health of the stream based on its biological integrity.

Biological Monitoring

Upper Rock Creek SPA
The water quality in the small headwater streams that are monitored for the Upper Rock Creek SPA has consistently been *good* since SPA monitoring began in 2004 and remains *good* in 2008. These headwater streams drain the major developments planned for the Upper Rock Creek SPA. One of these developments, Phase 1 of the Reserve at Fair Hill, broke ground in 2007.

Upper Paint Branch SPA
Most of the SPA development within Paint Branch has occurred in the Right Fork of the Upper Paint Branch. Pre-development conditions (1994-1998) were predominantly *excellent*. Current stream conditions (2006-2008) in the Right Fork have dropped slightly from *excellent* to *good*. It is anticipated that post-construction stream conditions in the Right Fork are likely to recover to near pre-construction level stream conditions because the composition of the biological community has not been greatly altered.

One station in the upper Left Fork of Paint Branch went from *fair* to *good* in 2008. SPA related development of an 8 acre residential development occurred from 2003 to 2004 and SWM has been functional and online since December 2004. It is unclear whether a correlation exists between SPA development activities and the stream condition in this watershed, but it appears that the small scale of development and the quick conversion likely helped mitigate any new impacts to stream conditions.

One Upper Paint Branch station has remained in *fair* condition since the inception of monitoring. This station is located in the headwaters of the Good Hope Tributary (in the vicinity of Peachwood Park). In 2008, Brown trout, one of the most sensitive fish species to stream degradation and water quality impairment in Montgomery County, were still present in the Upper Paint Branch SPA. Both the Upper Rock Creek SPA and Paint Branch SPA have an eight percent impervious surface cap.

Piney Branch SPA
Much of the new SPA development in the upper Piney Branch has occurred since 1998. Stream conditions dropped from predominantly *fair* to *fair* and *poor.* Two stations draining the older pre-SPA developments improved from *poor* condition in 2007 to *fair* in 2008. These stations are located in the Upper Piney Branch and are in close proximity to one another. The downstream station is in a portion of the Piney Branch within the older Piney Glen Village and Willows of Potomac developments. These developments started before the SPA program began.

One station in the headwaters of Piney Branch remains *poor*. This station drains a major portion of Traville. The Traville development (approximately 140 acres) represents a consortium of projects. While construction on some properties has been completed with S&EC converted to SWM since 2000, other portions just began stabilization and conversion in 2007 and 2008. Stream conditions will be monitored as new SPA developments are completed and SWM controls are online and functioning as designed.

Clarksburg SPA
In Clarksburg, stream conditions were in the *good* to *excellent* range from 1995 to 2002. Construction began in the Clarksburg SPA area in 2002; the same year in which a record drought also occurred. Much of the development in Clarksburg occurs within the drainage areas of small headwater streams. Benthic macroinvertebrates tend to better indicate water quality and stream health in these small streams over fish. The stream conditions in headwater areas undergoing development activities have been compared to a control set of headwater streams that have remained undeveloped.

Stream conditions between the control and test stations were initially very similar, but diverged in 2003. In 2008, all but one of the stations under construction in the Little Seneca Creek watershed remained in *fair* condition. One station near the bottom of the Town Center Tributary went from *fair* in 2007 to *good* in 2008. The drainage area to this station has portions of the Highlands of Clarksburg where construction has been completed and the land is stabilized, pre-SPA large lot development on the west, developing areas of the Clarksburg Village on the east, and wide forested stream buffers. Earth disturbing development activities have been reduced in this area, perhaps allowing for a recovery in stream conditions.

A station in the Wildcat Branch of Great Seneca Creek also improved from *fair* to *good* from 2007 to 2008 following site stabilization and conversion to stormwater management. Development of this formerly agricultural site consisted of construction of a cemetery, mausoleum, small chapel, and maintenance buildings. The impervious area of this property was small thus helping to minimize impacts.

Stream conditions in the Ten Mile Creek subwatershed remain in *good* condition. Brown trout—indicators of good water quality—were again found in Ten Mile Creek. It is not known whether these trout are naturally occurring, but no signs of fish stocking, such as fin erosion, were observed.

BMP Monitoring

Early BMP monitoring focused on the effects of urbanization on stream water quality through monitoring of stream conditions such as temperature and embeddedness (indicated by sediment settling). More recently, and at present, data collection of the stream's physical condition is paired with a focus on the ability of S&EC and SWM BMPs to remove contaminants. Current BMP monitoring evaluates percent mass removal of contaminants (removal efficiency) with a focus on sediment.

BMP monitoring demonstrates that the redundant features (i.e., the sequential use of structures in a treatment train) in SPA S&EC and SWM designs are effective in reducing stormwater runoff and decreasing pollutant loadings, and appear to be more effective than the use of individual structures. Placement of individual structures within the treatment train is also an important consideration. Since the inception of the SPA program, the Department of Permitting Services has consistently refined BMP design plans and reduced the size of the area draining to individual structures in an effort to improve pollutant removal efficiency and mitigate development impacts.

No new construction monitoring began in 2008, but monitoring of TSS was ongoing at eight projects. Three developments completed SWM BMP monitoring in 2008: two in Upper Paint Branch SPA and one in Piney Branch. All three projects were small properties (<10 acres) with limited development and short active construction periods. No trends between stream conditions and SPA development activities were observed. The small size of the projects and surrounding land use makes linking BMP performance with stream conditions at these locations difficult. More data is anticipated over the next few years from portions of SPAs where the majority of the subwatershed monitoring area is undergoing SPA development. There are insufficient data at this point in the development process to evaluate how far the SPA watersheds will recover from the negative effects documented during construction

Landscape Changes and LiDAR Imagery

The Clarksburg SPA continues to provide a unique opportunity to evaluate the effectiveness of BMPs in context with the ongoing changes to the landscape that occur as a result of development. This report provides a summary of the observations made from the latest Light Detection and Ranging (LiDAR) imagery and information from several of the stream flow and rain gages in Clarksburg.

Data show that the development process used in the Clarksburg test areas permanently changes the character of the landscape. These changes are cumulative and influence the receiving streams in many ways. The current cut-and-fill approach to site development permanently alters the overall topography, natural drainage patterns, and natural infiltration conditions. These disturbances to the landscape alter hydrology including base flow, characteristics of the stream channel, and the community of organisms living in the streams and adjoining wetlands. Water quality can be permanently altered as well.

Recommendations

A number of recommendations were provided in the 2007 SPA report. Follow-up on these recommendations has started. The State Stormwater Management Act of 2007 will soon require all jurisdictions to implement Environmental Site Design (ESD) for all new development to the maximum extent practicable. It will also require modification to all relevant codes and regulations as needed to facilitate the application of ESD.

The use of ESD is expected to further mitigate watershed-scale environmental impacts from development compared with more traditional strategies. In addition, the Maryland Department of the Environment is in the process of updating the sediment and erosion control regulations. It is anticipated that many of the code and regulatory recommendations in the 2007 and 2008 SPA reports will be acted upon as the changes resulting from the new SWM and sediment and erosion control requirements are made.

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1. Introduction

1.1 Purpose

The 2008 Special Protection Area Report is prepared and submitted according to the Montgomery County Code Chapter 19, Article V (*Water Quality Review: Special Protection Areas*), Section 19-67 (2001). The Special Protection Area (SPA) program is implemented through Executive Regulation 29-95: *Water Quality Review for Development in Designated Special Protection Areas*.

The Special Protection Area Report summarizes the monitoring conducted in streams and on *Best Management Practices (BMPs)* within Special Protection Areas (SPAs). SPA reports are submitted annually to the County Executive and County Council with a copy to the Montgomery County Planning Board.

1.2 Background

1.2.1 SPA Program

The Special Protection Area (SPA) program was initiated in 1994 by County law. According to the Montgomery County Code, Section 19-61(h), a Special Protection Area is defined as:

> "a geographic area where:
> (1) existing water resources, or other environmental features directly relating to those water resources are of high quality or unusually sensitive; and
> (2) proposed land uses would threaten the quality or preservation of those resources or features in the absence of special water quality protection measures which are closely coordinated with appropriate land use controls."

The County Council designated four areas within Montgomery County as Special Protection Areas (Figure 1.1). In 1994, The Clarksburg Master Plan approved the creation of the first SPA with the establishment of the Clarksburg SPA. In 1995, Piney Branch and Upper Paint Branch were designated as SPAs by separate Council Resolutions. The Piney Branch SPA lies within the Potomac Master Plan and Gaithersburg West Master Plan. The Upper Paint Branch SPA is covered by the Master Plans of Cloverly, Fairland, and White Oak. The Upper Rock Creek was designated as an SPA on February 24, 2004, with the adoption of the Upper Rock Creek Master Plan. All four SPAs have existing water resources or other environmental features that are of high quality or unusually sensitive.

Appropriate *land use* controls and management techniques help ensure that impacts from master planned development activities are avoided, minimized, or mitigated to the greatest extent practicable. Examples of these controls include limiting *imperviousness*, promoting *infiltration*, minimizing grading, and protecting natural features such as forested *riparian* stream buffers as part of land development projects. Special engineered water quality protection measures include *sediment and erosion control (S&EC)* and *stormwater management (SWM)* structures that go beyond current minimum standards.

The Piney Branch SPA and the Clarksburg SPA were created with very limited or no imperviousness cap for new development (in the Clarksburg Master Plan, there is a 15% impervious limit recommended for commercial sites on the west side of I-270). As the importance of minimizing imperviousness levels in order to maintain healthy stream conditions became better understood, the establishment of the Upper Paint Branch SPA was accompanied by an *Environmental Overlay Zone*, adopted in July 1997. The 1997 environmental overlay zone included a 10% impervious cap on new development, as well as restrictions on specific land uses that typically have significant adverse environmental impacts on sensitive natural resources. This Overlay Zone was amended in 2007 to revise the imperviousness limit for new development downwards to 8%. The Upper Rock Creek SPA designation was accompanied by an Environmental Overlay Zone on October 26, 2004, which designates an 8% imperviousness limit on new private residential subdivisions that are served by community sewer.

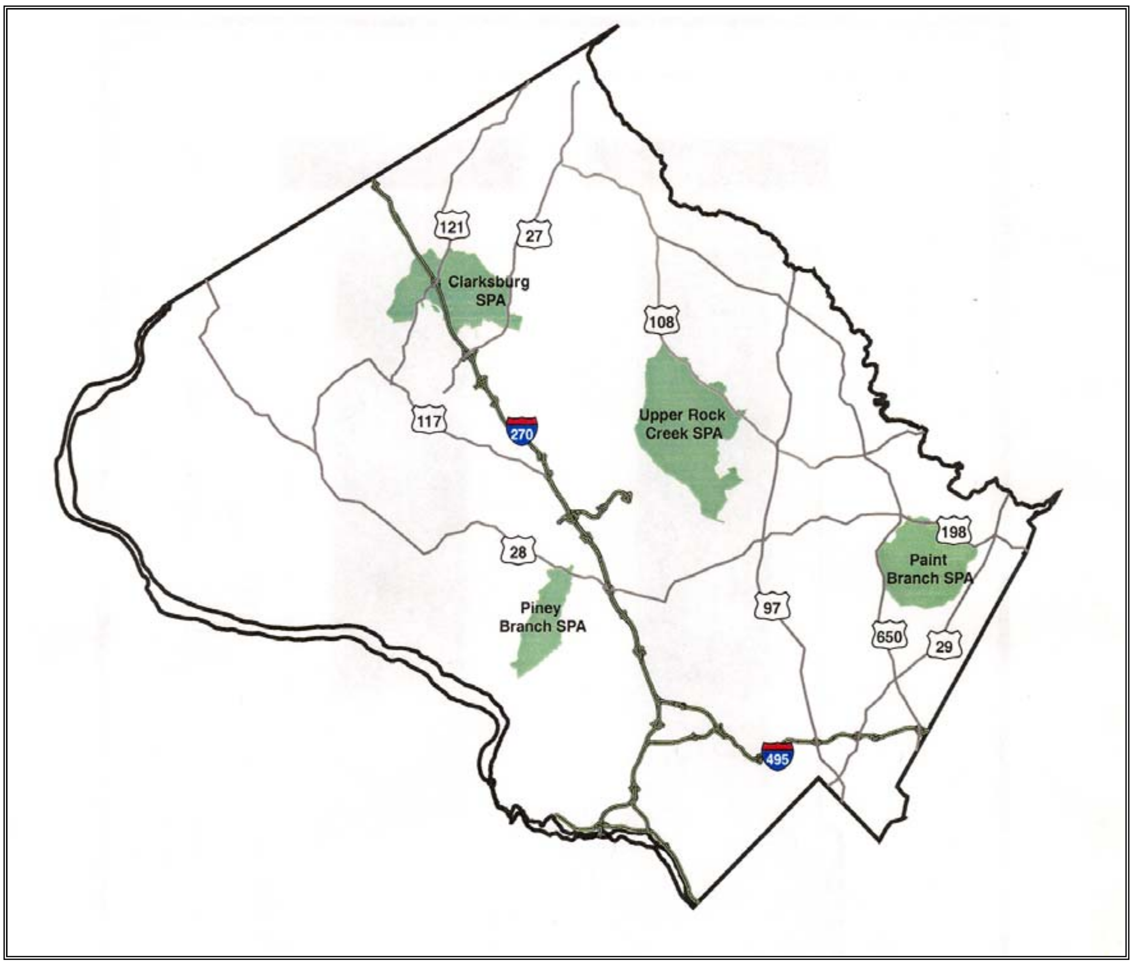

Figure 1.1. Location of Special Protection Areas in Montgomery County.

The SPA program requires the Montgomery County Department of Permitting Services (DPS), the Department of Environmental Protection (DEP), and the Maryland-National Capital Park and Planning Commission (M-NCPPC) to work closely with project developers from the onset of the regulatory review process to avoid or minimize adverse impacts to SPA stream conditions. SPA permitting requirements guide the development of concept plans for site imperviousness, site layout, environmental buffers, forest conservation, Sediment and Erosion Control (S&EC), and Stormwater Management (SWM).

Applicant requirements to carry out BMP monitoring are guided by performance goals (Section 2) designed for each development project. Achievement of the performance goals through the site plan design process and accompanying permitting requirements for sediment, erosion, and stormwater management controls requires close coordination between the project's design team and environmental, regulatory and planning agencies.

Despite the protection offered by the regulations, there are continuing conflicts between SPA goals for environmentally sensitive developments and other development requirements that sometimes foster increased impervious areas including: Master Plan-designated *transferable development right (TDR)* receiving areas, zoning density, construction sequence, and road grade and design requirements that require extensive *cut and fill*. These increased development pressures compete with the protection of natural stream systems.

1.2.2 Monitoring in Special Protection Areas

Sediment and Erosion Control (S&EC) and Stormwater Management (SWM) BMP monitoring are required as part of the SPA program. S&EC BMPs are installed on the construction site before initial land disturbing activities begin. They are designed to capture large volumes of sediment-laden runoff generated during construction. After construction is complete and the site is stabilized, SWM BMPs are installed to attenuate storm flows (quantity control) and capture *pollutants* (quality control). The time between installation of S&EC and conversion to SWM BMPs can take many years.

The SPA BMP monitoring program requires developers to monitor selected parameters to evaluate the ability of BMPs to minimize development impacts to the receiving streams. Additional discussion of developer requirements is provided in Section 2. The monitoring data is used to evaluate the design and function of SPA BMPs, link BMP performance to changing stream conditions, and guide future planning decisions.

During the first six years of the SPA program, BMP monitoring focused on stream-specific water quality parameters (temperature, *sedimentation*, *embeddedness*, and groundwater elevation). Starting in 2001, the program shifted to monitoring the pollutant removal efficiencies of structural BMPs. By monitoring pollutant removal efficiencies, the program could evaluate structural BMPs and the functional relationship to treating water quality. Results of SPA BMP monitoring are discussed in Section 3.

In conjunction with the monitoring performed by the developer, DEP performs physical stream characteristic (Section 4) and biological (Section 5) monitoring to study the overall effects of development on the watershed.

The Clarksburg Monitoring Partnership (CMP) is conducting research within the Clarksburg Master Plan area complimentary to the BMP monitoring conducted by the developers, and the biological monitoring conducted by DEP throughout the four SPAs. The CMP is a consortium of local and federal agencies and universities. It offers a collaborative approach to monitoring the long term aquatic ecosystem changes to the stream system resulting from the associated landscape transition from agricultural to medium and high density residential, commercial, and industrial land uses. Results of the CMP monitoring will supplement BMP monitoring in other SPAs and provide a comprehensive approach to document the effectiveness of land use planning and the implementation of modern S&EC and SWM BMPs.

The Clarksburg Monitoring Partnership includes:

- Montgomery County Department of Permitting Services
- Montgomery County Department of Environmental Protection
- Maryland-National Capital Park and Planning Commission
- University of Maryland, College Park campus
- USGS Water Resources Division, Baltimore, MD
- USGS Environmental Resources Center, Reston, VA
- Virginia Polytechnic Institute and State University
- George Mason University
- United States Environmental Protection Agency (U.S. EPA) Landscape Ecology Branch, Research Triangle Park, NC
- U.S. EPA National Risk Management Research Laboratory, Cincinnati, OH
- U.S. EPA Office of Research and Development, Atlanta, GA
- U.S. EPA Environmental Science Center, Ft. Meade, MD

The opportunity to study the development process from beginning to end will document how changes in *topography* and imperviousness affect the *hydrology* and *geomorphology* of the receiving streams.

The CMP is using a *Before, After, Control, Impact (BACI) design* approach (Fig. 1.2) to assess the land use changes and the impacts to stream conditions. Three test areas were selected: two in the Newcut Road Neighborhood and one in the Cabin Branch Neighborhood (Fig. 1.2). An undeveloped control area was established in Little Bennett Regional Park and a final developed control area was set up in Germantown (Fig. 1.2). All the test and control areas have United States Geological Survey (USGS) flow gages installed and are collecting continuous stream flow data over time. Two rain gages monitor area rainfall and document local rainfall intensities to correlate rainfall to stream flow. Light Detection and Ranging (LiDAR) imagery (Section 4.1) will assist in the mapping of landscape changes as a result of the terrain alterations in Clarksburg.

Changes in hydrology and geomorphology will be linked to changes in the *benthic macroinvertebrate* and fish communities. Other private and public researchers are collecting information on changes to groundwater levels and quality. Changes to stream ecosystem structure and function are being done through advanced studies of community metabolism, nutrient uptake and decomposition. This collaborative approach to monitoring long term change in an aquatic ecosystem has resulted in a comprehensive approach to document the effectiveness of land use planning and the use of modern S&EC and SWM BMPs.

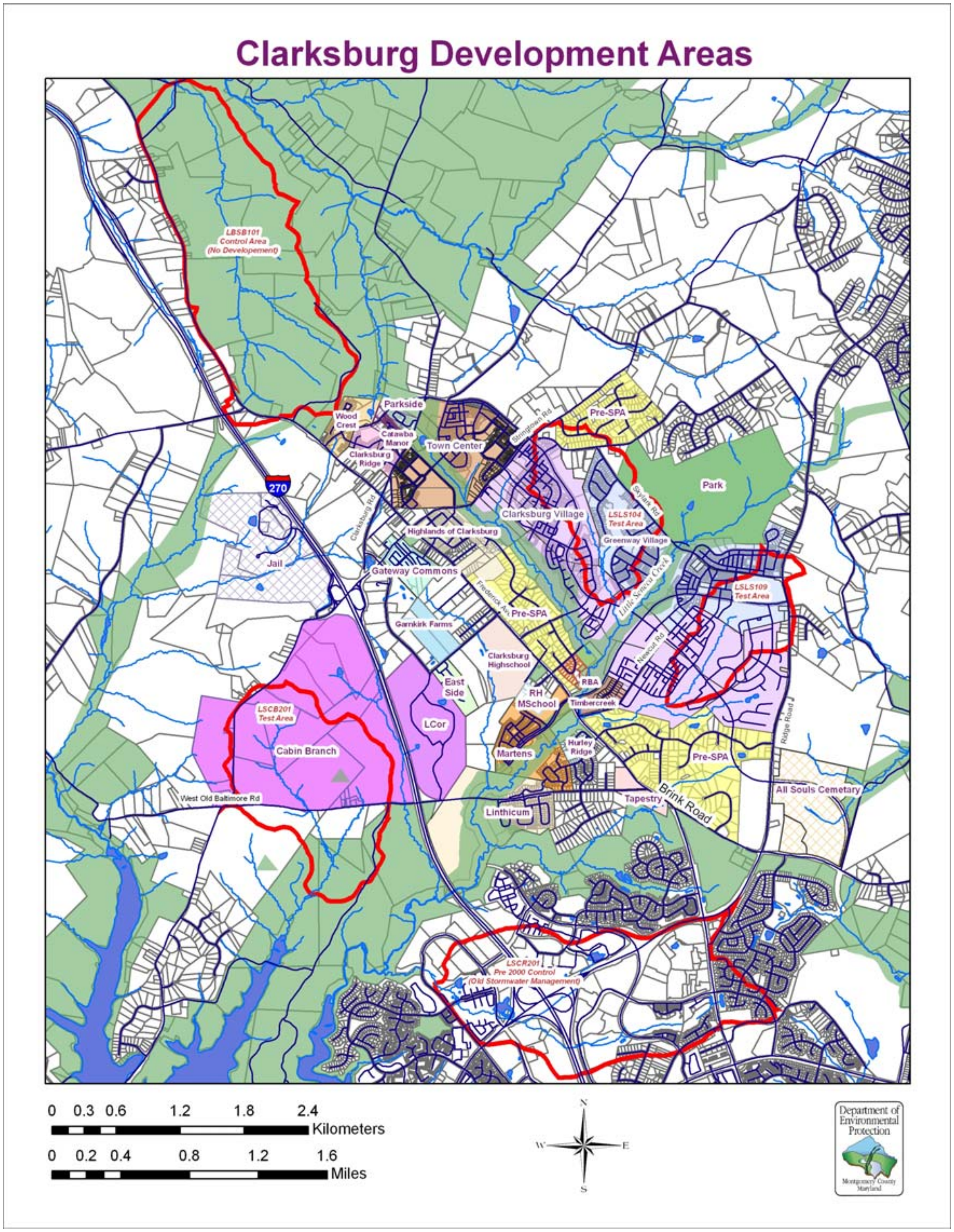

Figure 1.2. Location of the Clarksburg Monitoring Partnership BACI Three Test Areas and Two Controls Areas.

2. SPA Water Quality Review Plan and BMP Monitoring Review Process

Any development activity on privately or publicly owned land (unless specifically exempted) must go through the water quality review process. This section details the plan review process used to approve the design and layout of BMPs in an SPA. The section will also provide details on development of monitoring plans and requirements.

2.1 Water Quality Plan Review Process

2.1.1 Pre-application Meeting

Prior to submission of the *water quality inventory* and formal water quality plans for review and approval, an applicant for development must submit a written request and attend a pre-application meeting with DPS, DEP, and M-NCPPC. There are several purposes of the meeting. These include:

- Presentation of the proposed performance goals that are to apply to the development of the site layout;
- Discussion of the conceptual approach and possible locations of preferred structural and non-structural BMPs and their estimated suitability for achieving the performance goals;
- Discussion of approaches to minimize impervious surfaces or limit these surfaces to a regulatory cap, maximize protection of environmentally-sensitive areas such as streams, wetlands, and their buffers, and meet or exceed Forest Conservation Law requirements; and
- Development of innovative site layouts and linked best management practice options to maximize protection of water quality, stream habitat, and aquatic life.

Performance Goals

Before the pre-application meeting, DPS reviews the plans and establishes site-specific performance goals. DEP then works with DPS to determine how achievement of these goals can be documented through monitoring. Some performance goals are met by the site design and cannot be directly measured. DEP also advises the applicant of any available results and analysis of stream monitoring in the subwatershed of interest. M-NCPPC evaluates the plans and aids the applicant in ensuring the development project meets the Planning Board's Environmental Guidelines, minimizes or meets regulatory limits on impervious surfaces, and meets Forest Conservation Law requirements. DPS provides recommendations on S&EC and SWM measures that are appropriate for the proposed development. Following this discussion, the applicant circulates minutes recorded during the meeting for the group's evaluation and approval.

Performance goals aim to:

1. **Protect stream/aquatic life habitat.**
2. **Maintain stream base flow.**
3. **Protect seeps, springs, and wetlands.**
4. **Maintain natural on-site stream channels.**
5. **Minimize storm flow runoff increases.**
6. **Identify and protect stream banks prone to erosion and slumping.**
7. **Minimize increases to ambient water temperature.**
8. **Minimize sediment loading.**
9. **Minimize nutrient loading.**
10. **Control insecticides, pesticides, and toxic substances.**

2.1.2 Preliminary and Final Water Quality Plan Submission

Following approval of the pre-application meeting minutes, Preliminary and Final Water Quality Plans are developed and submitted to the respective lead agencies for their review and approval. Elements of these plans include preservation of *environmentally sensitive areas* and priority forest conservation areas, SWM concept plans, S&EC concept plans, documentation of impervious areas, BMP monitoring plans, and description of other mitigation practices including minimization of road widths and use of open section roads. Public notice of the submission of the Preliminary Water Quality Plan is made by DPS so that a public information meeting can be held if requested. The Planning Board gives approval to specific components of a water quality plan after DPS approves the plan components required under their review. Some plans can be submitted as a combined preliminary/final water quality plan.

With the exception of the Upper Paint Branch SPA and the Upper Rock Creek residential areas served by public sewer, only a water quality inventory instead of a full water quality plan is necessary if:

1) A project on agricultural, residential, or mixed use zoned property contains a proposed impervious area of less than 8% or a cumulative area of 10 or fewer acres and a proposed impervious area of less than 15% of the total land area.

2) A project on property zoned for industrial or commercial use consists of a cumulative land area of two or fewer acres covered by the development approval application.

A water quality inventory consists of most of the information that is typically required in a Water Quality Plan and includes a stormwater management concept plan, a sediment control concept plan, and documentation of impervious areas. A Water Quality Inventory does not require a monitoring plan with anticipated performance goals and does not require a public noticing period.

Once DPS approves its components of a Water Quality Plan, DPS issues a letter detailing its conditions of approval, including the BMP monitoring requirements. Applicants required to conduct monitoring must collect at least one year of data documenting baseline conditions prior to construction. DEP and DPS must approve the data and report submission documenting baseline conditions prior to any construction activities taking place on the site.

2.1.3 Issuance of Permits and Bonds

DPS is responsible for the issuance of permits and the enforcement of bonds. DEP works closely with DPS to ensure that monitoring is being completed as specified and that the construction site is in compliance. DPS sediment inspectors may issue a Notice of Violation if the site fails to remain in compliance. The Sediment and Erosion Control permit is closed and released following final inspection and approval of SWM as-built plans.

As of 2008, DPS has been issuing stream monitoring permits after the sediment and erosion control permit has been closed at sites required to do post construction monitoring. This allows an extra level of enforcement and assurance that the monitoring is being completed as required. The bond amount is established by DEP based on the anticipated cost of monitoring. The bond is released pending completion of post construction monitoring and approval of final data and report submissions by DEP and DPS. DPS continues to coordinate with DEP on the transfer of completed SWM facilities to DEP for structural maintenance and review and inspection of maintenance activities.

2.2 BMP Monitoring Review Process

The goal of the BMP monitoring program is to assess the effectiveness of SPA S&EC structures and SWM structures in maintaining water quality. A monitoring plan is designed to evaluate the effectiveness of BMPs, innovative site design and achievement of site performance goals. SPA BMP monitoring often includes monitoring of: groundwater elevations, groundwater chemistry, instream temperature, instream (surface water) chemistry, stream *base flow* and storm flow, *stream geomorphology*, *total suspended solids (TSS),* and pollutant loading reductions. Monitoring follows the procedures outlined in the Montgomery County Department of Environmental Protection Best Management Practice Monitoring Protocols (MCDEP 1998).

The information collected, when combined with data from the County's biological stream monitoring program, is used to evaluate the effectiveness of the County's current BMP designs over a range of drainage areas, land use, and impervious levels in protecting water quality. Recognizing practical site conditions, feasibility, and cost considerations, BMP monitoring is not required for all SPA development projects. There are many projects where, because of the relatively small property sizes or other reasons, no BMP monitoring is required.

2.3 SPA BMP Technology

The requirements for design of S&EC and SWM structures in SPAs currently exceed the minimum requirements set forth by the Maryland Department of the Environment (MDE). Redundancy and over-sizing of structures are the primary measures used to improve performance.

2.3.1 Sediment and Erosion Control (During Construction)

Sediment and Erosion Control Plans in SPAs are required to provide redundant treatment. In the beginning of the SPA program, DPS required the use of upland sediment basins/traps with an *outfall* to basins/traps further down grade or by providing basins with *forebays*. This approach was determined to be ineffective because the upland basin would typically discharge to disturbed areas or would be disturbed during construction. Recognizing these considerations, the design standards were revised. The current standard design requirement for S&EC in SPAs is to provide oversized basins with forebays near the outfall of the property, and promote the use of super silt fencing.

In addition, in an attempt to improve the efficiency of S&EC in SPAs, Montgomery County has adopted a number of features for S&EC in SPAs that are more stringent than MDE and County S&EC requirements for construction sites outside of SPAs. The adopted features include:

- basins with forebays,
- filter fence baffles,
- floating skimmers,
- dual basins in series,
- greater storage volumes, and
- utilizing combinations in the form of a treatment train to improve performance.

2.3.2 Stormwater Management (Post Construction)

The Maryland Department of the Environment (MDE) 2000 Maryland Stormwater Design Manual provides unified stormwater sizing criteria that specify how stormwater structures are designed. The three minimum components necessary to meet state stormwater management requirements are:

- *water quality volume (WQv)*
- *channel protection storage volume (Cpv)*
- *recharge volume (Rev)*

The water quality volume is approximately the first inch of rain over the impervious area and treats the "*first flush*" of contaminants coming off of impervious surfaces. In SPAs, redundant controls, also known as *treatment trains*, are required for stormwater quality control. Treatment trains utilize different types of non-structural and structural BMPs in series.

The allowable drainage area to any one filtering structure has decreased drastically since the SPA program started. Originally, there were only guidelines and no set limits for drainage areas to a filtering structure. The drainage area limit has decreased over the years to its current limit of three acres to a surface sand filter and one acre for all other water quality structures (including biofilters, infiltration trenches, and proprietary structures). This was done to increase the efficiency of the structures and to limit the area that is not treated (or is minimally treated) as the filtering structures become clogged and require maintenance. Additionally, runoff from areas intended for vehicular use must be pretreated prior to entering the water quality structure. This is typically done using a vegetated filter strip or a *hydrodynamic structure*.

The channel protection storage volume (also called the water quantity volume) is the volume necessary to hold the *one-year 24 hour storm*, approximately 2.6 inches of rainfall. Storage and slow release of the channel protection volume is intended to protect streams from erosion due to high velocity water scouring the banks. In the SPAs, the requirement for control of the one-year storm event was in place prior to the adoption of the 2000 MDE manual.

The recharge volume is intended to maintain the groundwater table and natural hydrology. Groundwater recharge has also been a requirement for developments in the SPAs from the beginning of the program. The adoption of the 2000 MDE Stormwater Design Manual provided additional methods to consider for providing groundwater recharge as well as the minimum recharge volume that must be provided.

Many of the elements set forth by MDE in the 2000 Stormwater Design Manual are a reflection of the design requirements that Montgomery County has been imposing on developments in SPAs. The requirements in the SPAs still exceed the requirements of MDE.

Recently, the Maryland Department of the Environment (MDE) proposed regulations to implement the Stormwater Management Act of 2007. These regulations would require the use of *Environmental Site Design (ESD)* practices wherever possible to control runoff and pollution from both new development and redevelopment. ESD would require integrating site design, natural hydrology, and smaller controls to capture and treat runoff to better maintain natural drainage pathways and minimize development impacts to receiving streams.

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3. BMP Effectiveness

SPA BMP monitoring projects are evaluated based on BMP efficiency, performance, and effectiveness. Developers are responsible for funding the monitoring within their property's limits to document achievement of the SPA performance goals set at the beginning of the SPA development process as part of the Water Quality Review Process detailed in Section 2.1.

BMP efficiency compares the amount of pollution entering the BMP to the amount of pollution leaving the BMP. Either pollutant concentrations from grab samples or loading values from flow-weighted samples collected by automated samples are used for this measure.

BMP performance evaluates how well the BMP is removing pollutants compared to literature values.

BMP effectiveness is the ability of the BMP and site design to meet one or more of the SPA program performance goals.

3.1 2008 SPA BMP Monitoring Status

Status of the BMP monitoring projects being conducted in 2008 as part of the SPA program is shown in Figure 3.1. A list of parameters monitored per project is located in the Technical Appendix.

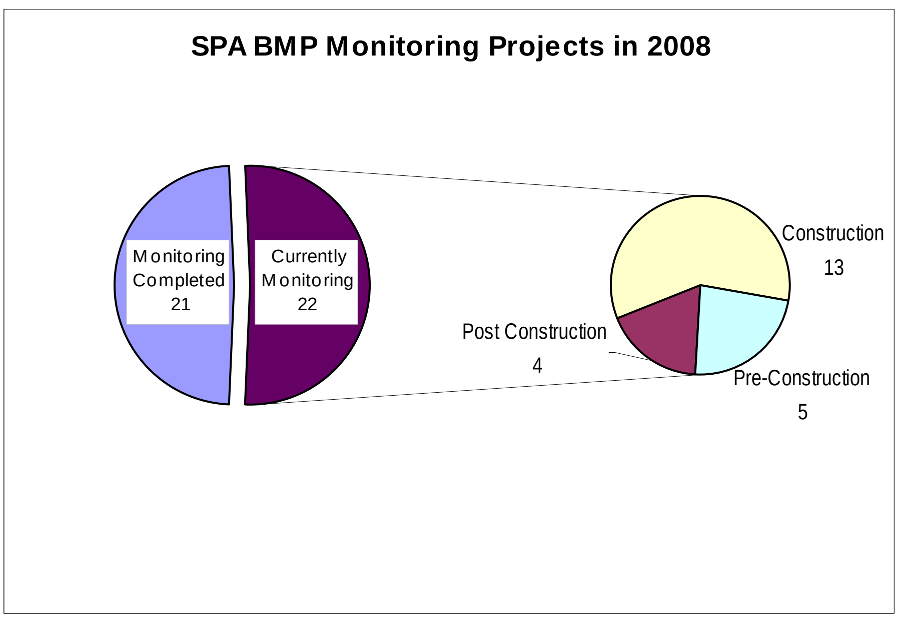

Figure 3.1. SPA BMP Monitoring Project Completion Status in 2008.

Twenty-one projects have completed monitoring, seven of which satisfied monitoring requirements in 2008. A list of completed projects and monitored parameters with years monitored are located in the Technical Appendix. Of the 22 projects continuing monitoring in 2008, the majority (59%) were collecting data on during construction conditions.

Much of the Clarksburg Special Protection Area remains under construction (Fig. 3.2). All Souls Cemetery, Catawba Manor, and Timbercreek satisfied monitoring requirements in 2008. Catawba Manor monitoring failed to produce useable results and the developer submitted a payment in lieu of continued monitoring. Five projects have not broken ground, but the Cabin Branch Neighborhood is anticipated to begin construction in 2010. Portions of the Clarksburg Town Center, Clarksburg Village, Greenway Village, and Summerfield Crossing are nearing the post construction monitoring phase. Parkside has been issued a post construction stream monitoring bond and will begin monitoring in summer 2009.

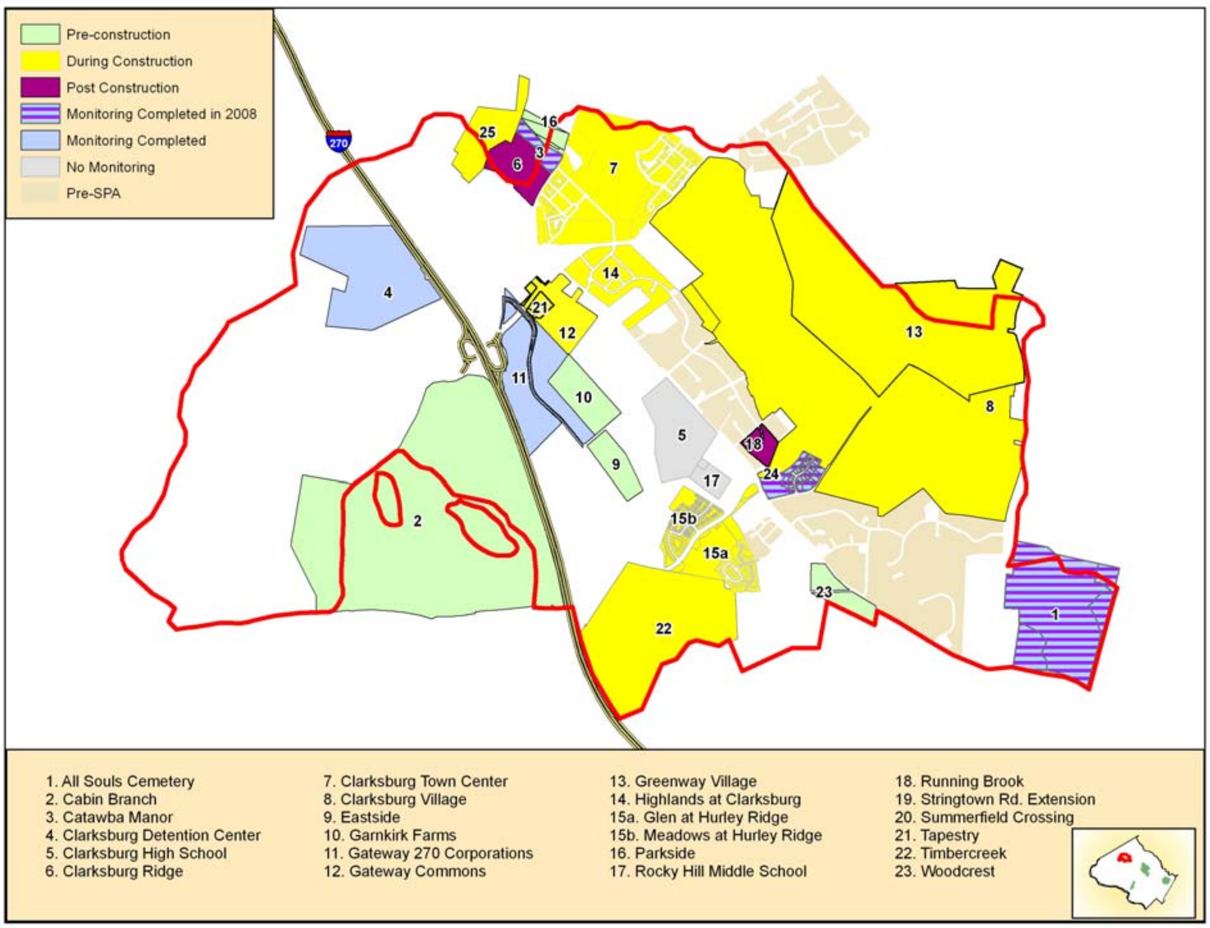

Figure 3.2. 2008 Status of Clarksburg SPA Monitoring Projects.

The majority of projects in the Upper Paint Branch and Piney Branch SPAs have completed monitoring. Three monitoring projects in Paint Branch (Fig. 3.3) were completed in 2008: Cloverly Safeway, Sniders Estates, and Briggs Chaney/US 29 Road Improvements. It is anticipated that Hunt Lions Den and Forest Ridge data collection will be completed in 2009. A post construction stream monitoring bond has been posted for Briarcliff Meadows and data collection on post construction groundwater levels and chemistry began in early 2009. Automated sampling of two SWM BMPs, a sand filter and biofilter, began in summer 2009. One property, Peach Orchard/Allnut, was turned over to the State Highway Administration (SHA) as part of a mitigation package for the Inter-County Connector (ICC).

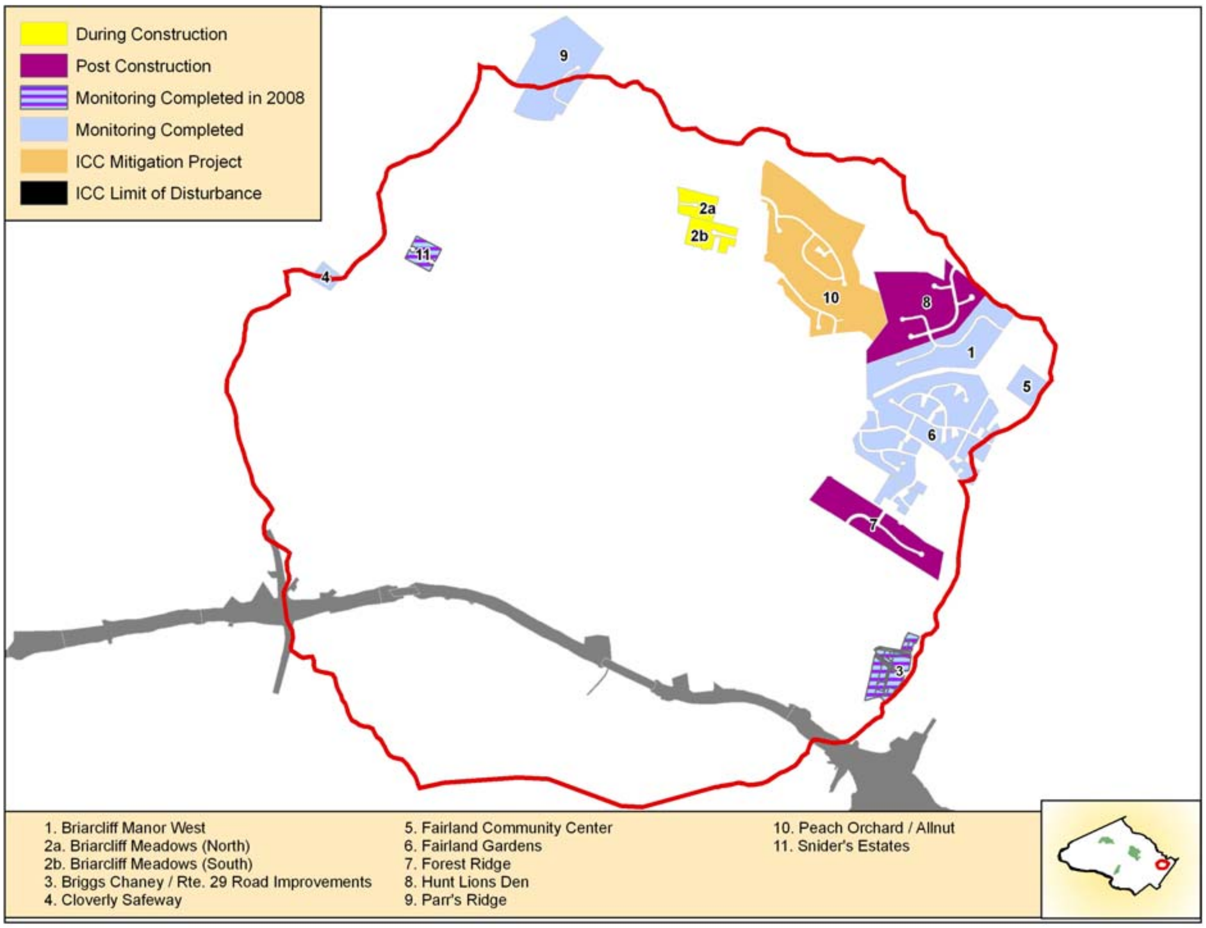

Figure 3.3. 2008 Status of Upper Paint Branch SPA Monitoring Projects.

The Piney Branch SPA is near the maximum build out allowed under the Master Plan. Analysis conducted in 2005 by the MNCPPC found that 5%, or 121 acres, of the 2,369 total acres in the Piney Branch SPA remain available for development (MCDEP 2008). Two large developments (~433 acres), Willows of Potomac and Piney Glen Village, were constructed prior to the establishment of the Piney Branch SPA and lack the special land use controls and water quality protection imposed under SPA requirements.

Monitoring of the SWM BMP treatment train at Willow Oaks was completed in 2008 and the only monitoring project still active is Traville (Fig. 3.4). All structures were in the process of being converted to SWM or converted to stormwater management in 2008, but post construction monitoring was delayed until a monitoring bond for the post construction period could be posted.

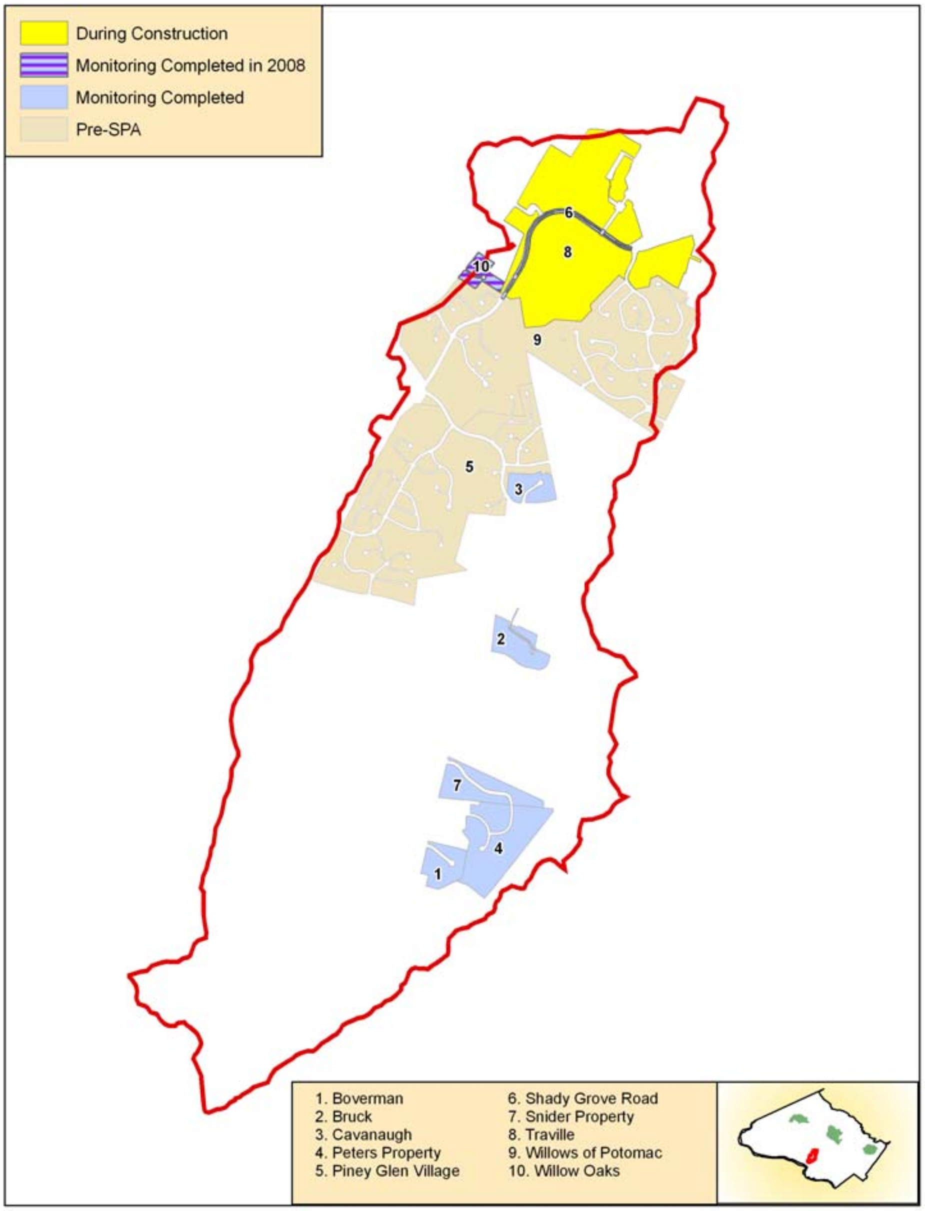

Figure 3.4. 2008 Status of Piney Branch SPA Monitoring Projects.

The Upper Rock Creek SPA has two projects currently conducting monitoring (Fig. 3.5). The Reserve at Fair Hill began monitoring during construction conditions in May 2007. The Preserve at Rock Creek has completed pre-construction monitoring and data collection will continue once construction begins.

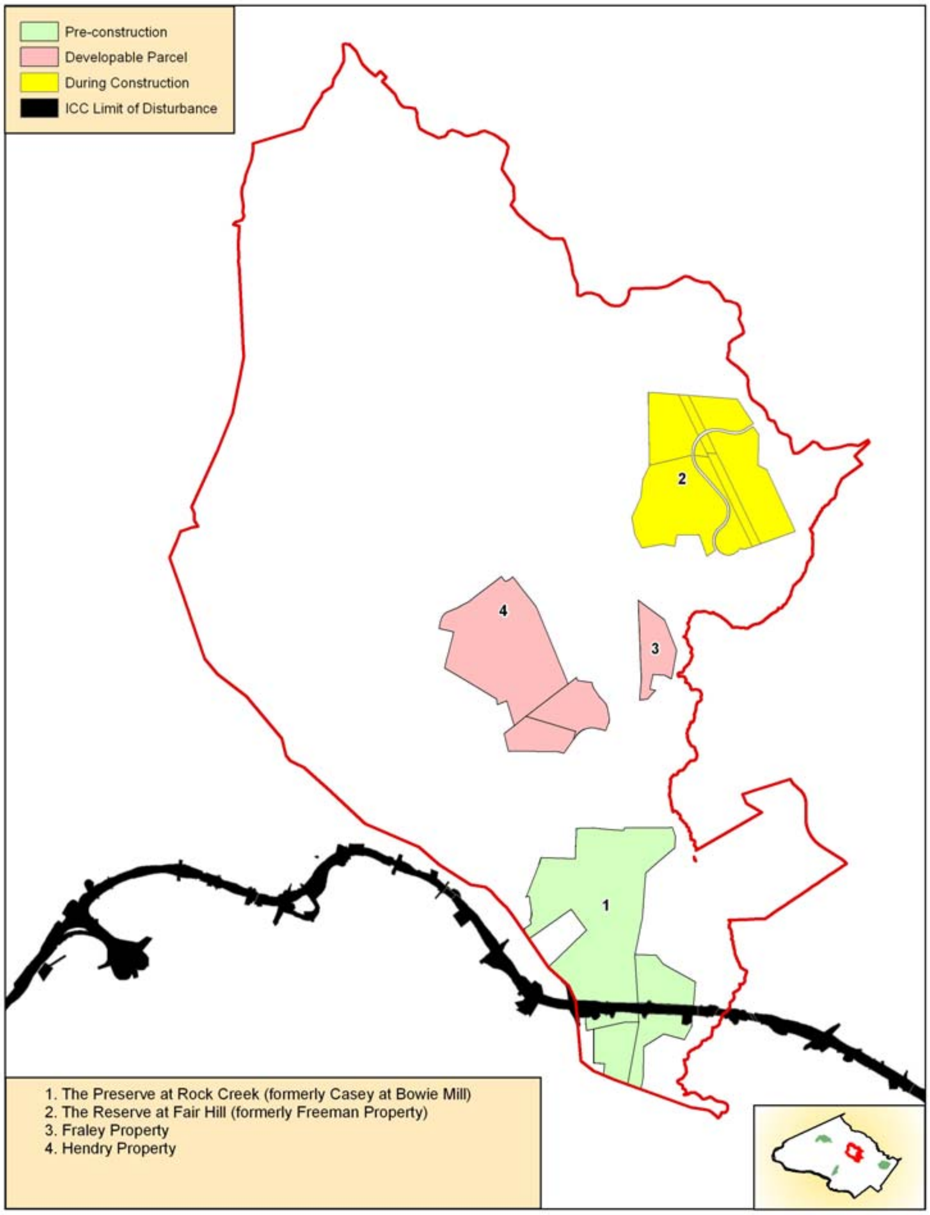

Figure 3.5. 2008 Status of Upper Rock Creek SPA Monitoring Projects.

3.2 Water Quality Monitoring

BMP monitoring prior to 2001 evaluated BMP effectiveness by stream and hydrological conditions as well as water quality parameters at the stormwater outfall (where the stormwater for the site discharges into the receiving stream) (Fig. 3.6). Later monitoring paired data collection on the stream's physical characteristics with an additional focus on specific structural BMP performance. BMP monitoring evaluates pollutant removal efficiency by measuring the amount of pollutant entering a BMP versus the amount of pollutant exiting a BMP (Fig. 3.6).

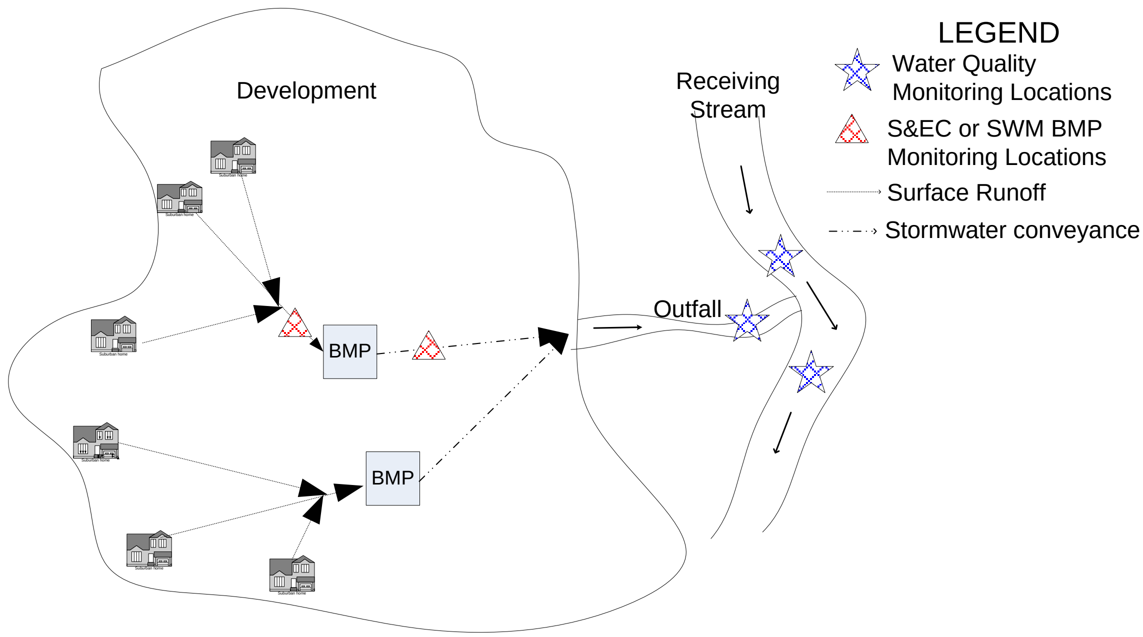

Figure 3.6. Schema Representing SPA BMP Monitoring Locations.

3.2.1 Stream Temperature

Two projects required to conduct stream temperature monitoring were completed in 2008. The Timbercreek development (Clarksburg SPA) monitored stream temperatures in Little Seneca Creek upstream and downstream of a stormwater management facility. Temperature did not appear to be impacted by construction activities. The SWM treatment train consisted of a dry pond for quantity control and vegetated and infiltration swales discharging to a surface sand filter provided quality control. The SWM treatment train did not produce a warming or cooling effect into the receiving area of Little Seneca Creek. It is possible that the wetland area present between the SWM outfall and Little Seneca Creek aided in promoting infiltration of the stormwater instead of it entering the stream directly. Stream temperatures monitored at Timbercreek were highly influenced by the lack of riparian tree cover and diurnal air temperature fluctuations and weather conditions; conditions that existed prior to any development activity.

Stream temperature monitoring at The All Souls Cemetery was conducted at one location in Wildcat Branch, a tributary to Great Seneca Creek. Stream temperature monitoring began in 2001 and continued through the construction phase and two years after construction was completed. Results of this monitoring were inconclusive. There appeared to be some instances where temperature spikes occurred in conjunction with rain events, but it is unclear whether these temperature spikes were the product of the SWM dry pond, the development itself, air temperature, the limited base flow of the Wildcat Branch, or some other factor or combination of factors. Additionally, the monitoring location was about 1000 feet below the SWM facility outfall and any temperature effects produced by the discharge from the BMP could have dissipated before reaching the monitoring station. A more upstream location was not selected when establishing the monitoring plan because it was believed that there would not be sufficient base flow to submerge the logger.

Ten completed projects were required to monitor stream temperatures. The majority (eight properties) identified no thermal impacts, indicating that the goal of minimizing temperature impact was achieved. It is possible that dilution effects may have buffered thermal impacts, as some properties release stormwater to larger, second order streams. The results from All Souls Cemetery and Cavanaugh (Piney Branch SPA) were inconclusive. A lack of conclusive results at Cavanaugh was due to inconsistencies with data collection, a lack of calibration records, and consultant coordination.

3.2.2 Embeddedness

Six of the twenty-one completed projects were required to submit data on embeddedness, which measures the extent to which sediment has covered the stream bottom and filled in spaces between the rocks, cobble, and gravel. No additional results were produced during the 2008 monitoring year. Results from four projects indicate there were no impacts. Briarcliff Manor West, in the Upper Paint Branch SPA, had the highest embeddedness scores during construction at a station below the sediment pond outfall, although scores were not drastically different from baseline. Embeddedness levels declined during post-construction. The Shady Grove Road project, in the Piney Branch SPA, also had embeddedness impacts during construction, but post-development monitoring data indicated embeddedness was reduced to pre-construction levels.

3.2.3 Groundwater Levels

Groundwater level monitoring was conducted at eight of the completed projects. Monitoring requirements were modified for two of these projects and only six projects have data available for analysis. Three projects showed no impacts to groundwater, one project was deemed inconclusive, and two properties experienced groundwater impacts.

Groundwater level monitoring at two wells was completed in 2008 at the Timbercreek Property in Clarksburg. One well, MW-1, was located down-gradient of a stormwater management facility, and the other, MW-2, was located up-gradient of a stormwater management facility. A site plan with monitoring locations and well details are provided in the technical appendix. Groundwater elevations in the down-gradient well remained consistent throughout the monitoring and did not fluctuate drastically from pre-construction conditions, suggesting that construction activities and stormwater management structures neither decreased nor promoted groundwater infiltration.

Groundwater levels at the up-gradient well, however, were impacted by development. This well went dry in December 2004 and groundwater levels remained at or below the bottom of the well through the conclusion of monitoring in November 2007. The reduction in groundwater levels coincides with the completion of the Timbercreek development and the stormwater management structures coming online in December 2004. The engineered stormwater conveyance may have redirected storm flows into the SWM facilities, interfering with the natural infiltration. This change in hydrology did not appear to produce a response in stream temperatures upstream and downstream of the Timbercreek development. An impact to the biological communities in Little Seneca Creek downstream of the development could not be discerned. The redirection of storm flow and engineered recharge areas (such as *vegetated swales* and *infiltration trenches*) were able to offset any effect this localized reduction in groundwater levels would have had to the base flow in this portion of Little Seneca Creek.

Monitoring of groundwater elevations at Briarcliff Manor West (Upper Paint Branch) was completed in 2006. Before and during development, the data from the Briarcliff Manor West property (Upper Paint Branch SPA) matched very well with a USGS well that has been used as a control (Figs. 3.7 and 3.8). Following development, groundwater levels at Briarcliff Manor West were reduced in relation to the USGS well. This indicates that groundwater recharge has been affected by development of the site.

3.2.4 Groundwater Chemistry

Groundwater chemistry was monitored at two of the completed projects, Clarksburg Detention Center (Clarksburg SPA) and the Boverman Property (Piney Branch SPA). Data from both projects produced inconclusive results. The compounds monitored for each project are located in the Technical Appendix. No newly-completed projects were required to monitor groundwater chemistry. BMP monitoring of groundwater chemistry before and after construction at one well at the Clarksburg Detention Center (Clarksburg SPA) revealed nitrate levels above the EPA Drinking Standard of 10 mg/L. Levels ranged from 15.0 to 31.2 mg/L. During the late 1970's, a parcel of land near the well was used as a site for disposal of sewage sludge, which may explain the elevated levels.

3.2.5 Instream Chemistry

No projects completed in 2008 were required to monitor instream chemistry. However, instream chemistry monitoring through all phases of development was required at one project completed in 2005. Monitoring data are located in the Technical Appendix. *Grab samples* were collected in a tributary of Piney Branch, Sheep's Run, directly below the area where the Snider's Property SWM outfall discharges. Monitoring revealed an increase in TSS concentrations during construction, which decreased after site stabilization and subsequently returned to pre-construction levels during the post-construction period. Monitoring results also suggested that *total Kjeldahl nitrogen (TKN)* levels may have been slightly elevated during the conversion process of S&EC to SWM. As part of the development process, SWM Pond #1 was retrofitted from a farm pond and the portion of Sheep's Run was fenced from livestock. Preventing any mowing or trampling by livestock of the area adjacent to the stream aided in the protection of stream habitat and aquatic life.

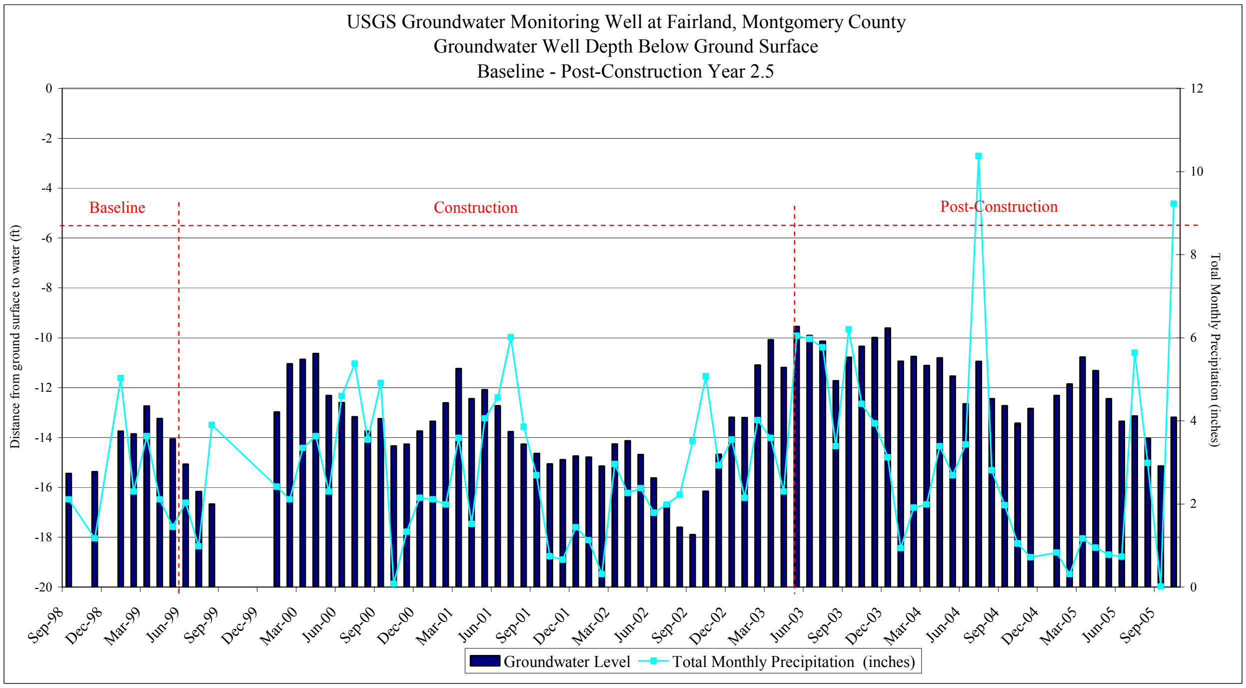

Figure 3.7. Briarcliff Manor West (Upper Paint Branch SPA) Groundwater Level Monitoring.

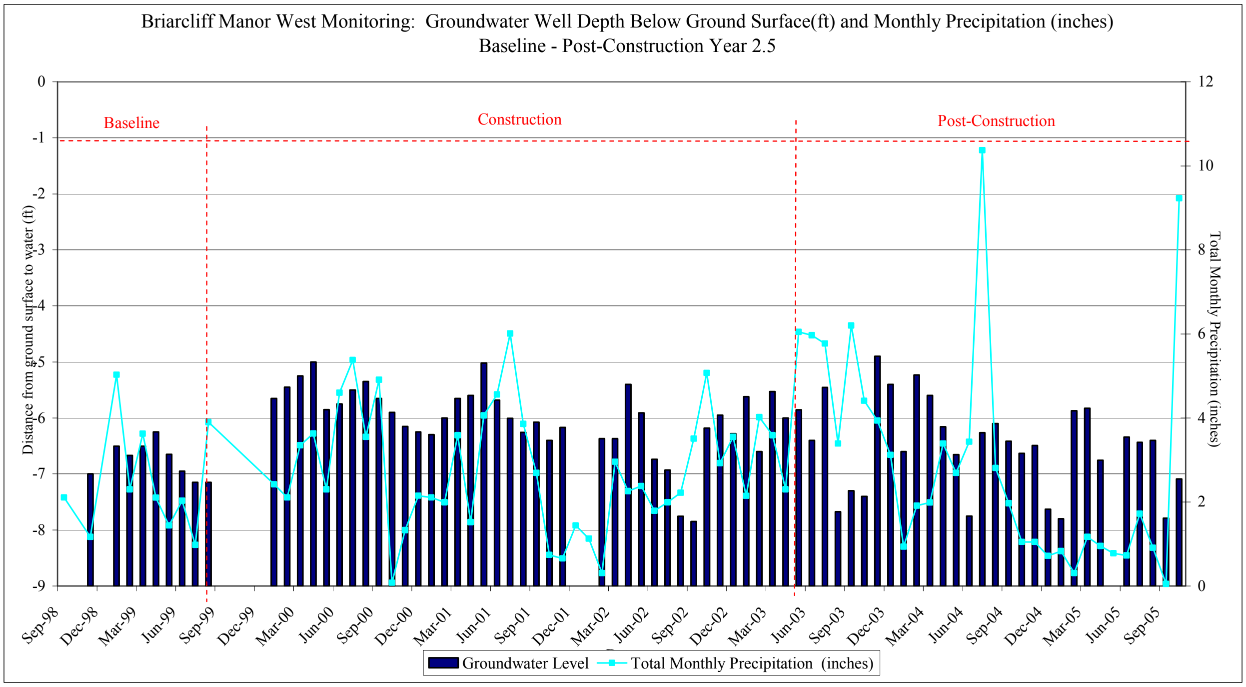

Figure 3.8. USGS Fairland (Upper Paint Branch SPA) Groundwater Level Monitoring.

3.2.6 Continuous Stream Flow

Continuous stream flow was required at four of the completed projects. Unfortunately, stream flow sampling proved extremely challenging and very little useable data were produced from this monitoring. Issues with how equipment was installed and maintained, general equipment failure, and errors and inconsistencies with how data were reported, managed, and stored impeded interpretation of the data. Additionally, monitoring of stream flow was terminated at two projects: one was ended due to equipment failure and lack of data, and the other because the staff gage plate was catching debris and redirecting flow, causing stream erosion.

Current SPA surface gages are operated by Montgomery County, U.S. EPA, and the USGS through several joint funding agreements to improve data collection and availability. Continuous stream flow monitoring is also required at several developments in the Clarksburg SPA (Clarksburg Town Center, Clarksburg Village, Gateway Commons, and Greenway Village), as well as Traville in Piney Branch SPA). Results of this monitoring will be presented as the monitoring requirements are fulfilled.

3.2.7 Cross Sections

Two completed projects monitored cross sections to document changes to the shape of the stream channel in response to changes to flows of water and sediment. There was no impact to the shape of the stream channel in the monitored areas of Briarcliff Manor West and the stream channel geometry and flow regime were similar to pre-construction monitoring. There were minor changes observed at the downstream cross section that appeared to be caused by the adjacent staff gage installed for flow monitoring. The staff plate of the gage was collecting debris which forced flows into the left of the bank.

All Souls Cemetery monitoring of two cross sections in Wildcat Branch was completed in 2008. Both cross sections were located below the BMP outfall and experienced impacts from development. Both cross sections experienced erosion to the right bank and incision to the stream channel. The greatest changes in channel shape and area were between 2004 and 2005 and from 2006 to 2007. Little change was observed between the 2007 and 2008 surveys. It is likely that the conversion from agricultural land use to a cemetery, chapel, mausoleum complex, and maintenance building delivered sediment to the stream. Historical farming practices or crop cover may also have had an effect on the stream. Locations of the monitoring stations and plots of the cross-sections are located in the Technical Appendix.

3.2.8 Best Management Practice Sampling

As stated previously, monitoring of water quality parameters at the stormwater outfall (Fig. 3.6) was sometimes required in early SPA projects. The results presented in this section discuss projects where samples were only collected from the SWM outfall.

For the Route 29/Briggs Chaney Road widening and road improvement project in the Upper Paint Branch SPA, grab samples at the outfall of SWM Pond B were collected to monitor the structure's effectiveness while the roadway adjacent to the pond was restructured and widened. Total suspended solid (TSS) *grab samples* of runoff were collected from two storms prior to construction, three storms during construction and one storm after completion of construction. For each storm, three samples were collected from the pond outfall within 12 hours of the end of a rain event. Samples were taken at half hour intervals. Each discrete sample was analyzed separately and averaged together during analysis. The rate of flow from the facility was measured (in cubic feet per second) as the samples were collected.

During July 2003 through October 2007, SWM Pond B appeared to perform consistently, with the exception of one storm event. During the December 8, 2004 storm event, TSS results were much higher than any other monitored event. Brown water was observed in the pond and a "large volume of brown water flowing from the outfall was observed" as the result of a large amount of rain over a short duration (RKK 2008). Additionally, a large amount of land disturbance involved with the widening of Briggs Chaney Road and construction of the water quality swale occurred during the month prior to the storm event. Other than the December 2004 event, measurements from during construction generally fell within the range of the pre and post construction measurements. A location map, timeline of construction, data, and photographs of the structure are located in the Technical Appendix.

Several completed projects monitored total suspended solids at sediment and erosion control structures during construction using grab sampling. These results are discussed in Section 3.3.1. Three completed projects conducted stormwater management BMP monitoring: Willow Oaks (Piney Branch SPA), Cloverly Safeway, and Snider's Estates (Upper Paint Branch SPA). Results of this monitoring are discussed in Section 3.4.

3.3 Sediment and Erosion Control (S&EC) BMP Monitoring

S&EC BMP performance is evaluated during construction by measuring the removal efficiency of total suspended solids (TSS). Information on evaluating BMP efficiency using percent removal is provided in the Technical Appendix. The removal efficiency is calculated from either grab sampling or automated samples that collect storm flow entering and leaving an S&EC structure. Results of the two sampling methods cannot be directly compared and are discussed separately.

3.3.1 Grab TSS Sampling

A manual grab sample is collected by inserting a container into the flow at the inlet(s) and a separate container into the flow at the outfall of a structure. Data collected via the grab sample method can be used to represent pollutant removal efficiency as the difference (expressed as a percentage) between the concentrations of pollutants entering the structure (*influent*) versus the concentration leaving the structure (*effluent*), but is not representative of the entire storm event. Monitoring using grab samples in the SPAs is conducted within 24 hours after qualifying storm events (typically events yielding total rainfall of at least 0.5 inches). Concentrations of suspended sediment and chemical parameters can vary throughout a storm event, with the first inch of rain over the impervious area (known as the "first flush") often being the most pollutant-laden portion of the runoff. Grab sampling may not always capture the first flush and offers only a snap shot of the pollutant concentration at a discrete point in time.

A total of 113 grab samples have been collected from 2002 to 2008 from SPA S&EC structures (Technical Appendix). Data from one project, Traville, in the Piney Branch SPA, were excluded from the analysis due to a high prevalence of sampling configuration issues and non-representative data. Grab samples were required for some early projects as part of the original monitoring plan and are still presently collected at these projects still under construction (such as Clarksburg Village). In some cases, grab samples were collected in lieu of automated samples during equipment failures. The practice of collecting grab samples or other types of samples as a substitute for automated flow-weighted composite samples is no longer acceptable for SPA BMP monitoring.

Monitoring results from grab samples (Figure 3.9) continue to show S&EC structures receiving dirty, sediment-laden water are generally effective at reducing stormwater TSS concentrations, but with some variability in performance.

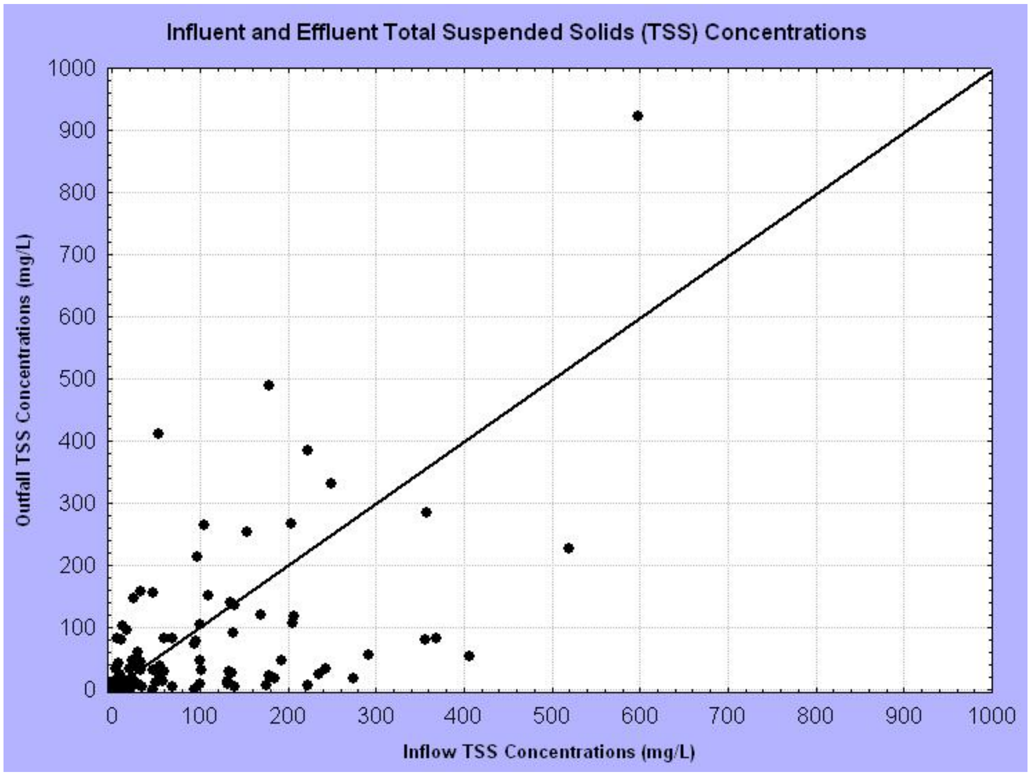

Figure 3.9. Inlet and Outfall TSS Concentrations (Grab Sample Data) From Monitored Sediment and Erosion Control Structures. For Some Structures, Inlet TSS Concentrations Represent a Calculated Average Value for Multiple Inlets.

S&EC structures receiving dirty, sediment-laden water (likely to occur during the early development periods involving cutting, filling, and grading) resulted in larger TSS concentration reductions than samples with concentrations lower than 100 mg/L (which are often collected later in the construction process). For storm events where influent TSS concentrations were greater than or equal to 100 mg/L, the median TSS removal efficiency was 70.6% (Fig. 3.10). At concentrations below 100 mg/L, the results were much more variable with a median removal efficiency of only 18.1% (Fig. 3.11).

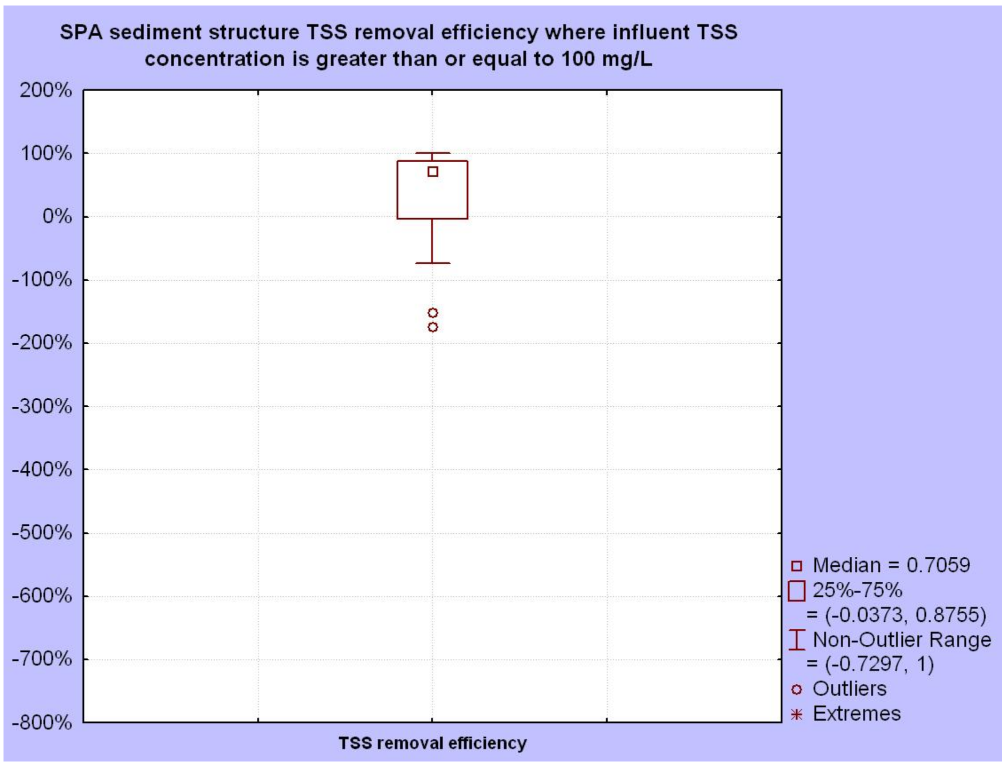

Figure 3.10. Percent Difference of Inlet and Outlet TSS Concentrations From Grab Samples Where Influent TSS Values are Greater Than or Equal to 100 mg/L.

In some cases, water leaving the S&EC BMP contained higher concentrations of TSS than the entering water. The less polluted water (less than 100 mg/L) entering the S&EC structures could be the result of the sampling event taking place fairly late in the grading and site preparation process during the period where most of the cut and fill were completed. It may also be the result of soil compaction as final lot and road grades were completed to maintain the final surveyed grades. The higher outfall concentrations could be from the resuspension of fine clays and silts already in the control structure basin. As projects get closer to completion and less exposed earth is present on the site, there may be more sediment accumulated from prior storms being washed out of structures than is entering and settling in the trap.

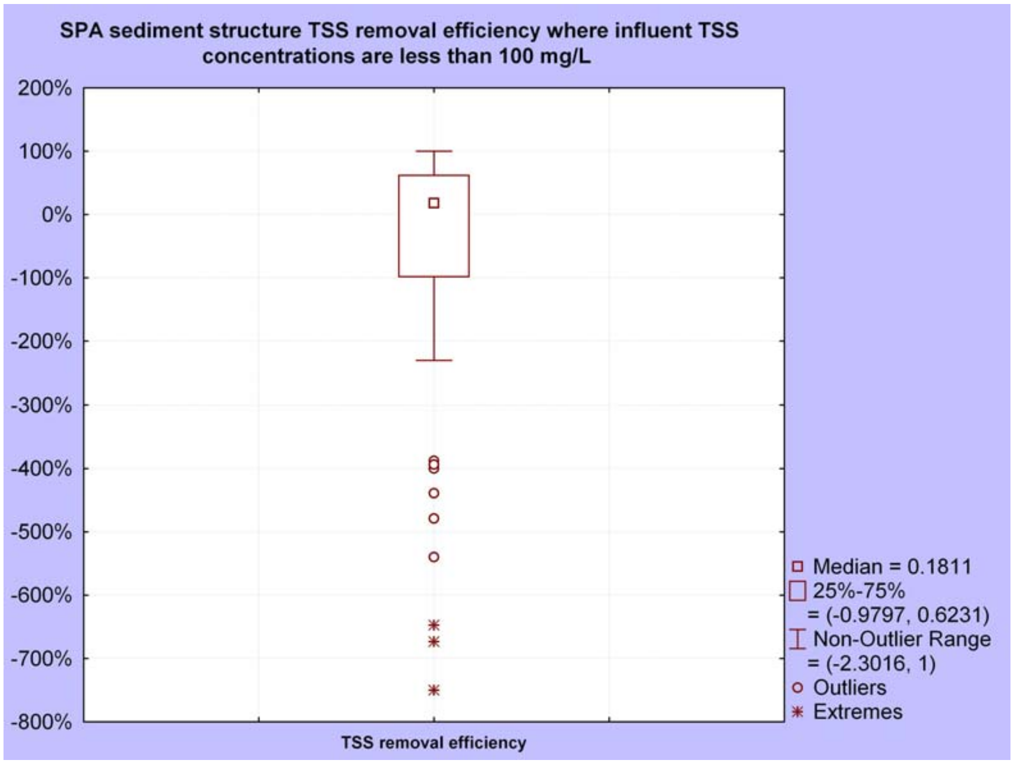

Figure 3.11. Percent Difference of Inlet and Outlet TSS Concentrations from Grab Samples Where Influent TSS Values are Less Than 100 mg/L.

3.3.2. Flow-weighted Composite TSS Sampling

Background

Automated samplers are used to collect stormwater samples at intervals based on the estimated duration of the storm event. Following the event, samples are manually composited based on the flow to characterize the quality of stormwater discharge. Storm load efficiencies are then calculated and BMP percent removal efficiency is used to compare the mass of pollutant entering the S&EC or SWM BMP structure versus the mass of pollutant leaving the structure.

Flow-weighted composite BMP sampling can be reported using several different methods (Strecker et al. 1999). Individual storm load efficiency was the method selected to analyze the SPA monitoring results. Load efficiency of a structure is considered more accurate than examining efficiency independent of water volume, as is the case for grab samples. Due to the limitations of grab sampling, data collected from the two methods cannot be directly compared.

Although a better measure of BMP efficiency, DEP and the consultants who perform the flow-weighted composite sampling for S&EC have found it extremely challenging to obtain quality data for a number of reasons including:

- Equipment problems,
- Structure configurations that do not allow for accurate sampling,
- Unaccounted for groundwater inputs, and
- Weather-related difficulties (i.e. insufficient rain amounts, storm events outside of normal business hours).

The configuration of a structure can change frequently as construction progresses, and occasionally some inlets stop receiving flow or additional inlets are installed between sampling events. Furthermore, some monitored structures were found to have intersected groundwater during installation. This resulted in continuous flow leaving the structure, making it difficult to define a storm flow event. Backwater at the inlets can make it impossible to capture a positive or accurate flow needed to calculate a pollutant load. Low flow entering or leaving the structure, as well as equipment anomalies and malfunctions, have also prevented the collection of flow-weighted data.

A limited amount of flow-weighted storm sampling data is available for S&EC basins. Currently, only five projects are conducting this sampling, all of which are in the Clarksburg SPA. Some projects have not been able to produce meaningful data due to sampling difficulties. Additionally, one project failed to conduct 2008 monitoring altogether due to lack of developer payment to the monitoring consultant.

Automated Sampling Results

Flow-weighted composite samples were consistently obtained for three projects: Clarksburg Town Center, Gateway Commons, and Stringtown Road Extension. Although composite samples were successfully collected, there were still inherent problems for each project. Aerial photos, site plans with sampling locations, basin information, and TSS concentration data are provided in the Technical Appendix.

Automated sampling data from 21 storm events (Technical Appendix) indicates that the three S&EC structures monitored were receiving very sediment-laden water and were effective at reducing the loadings exiting the structures (Fig. 3.12). This overall success may be partially attributed to the reduction in flow as it leaves the S&EC basins. In some instances, no measurable flow exited the structures and nearly all of the sediment was retained.

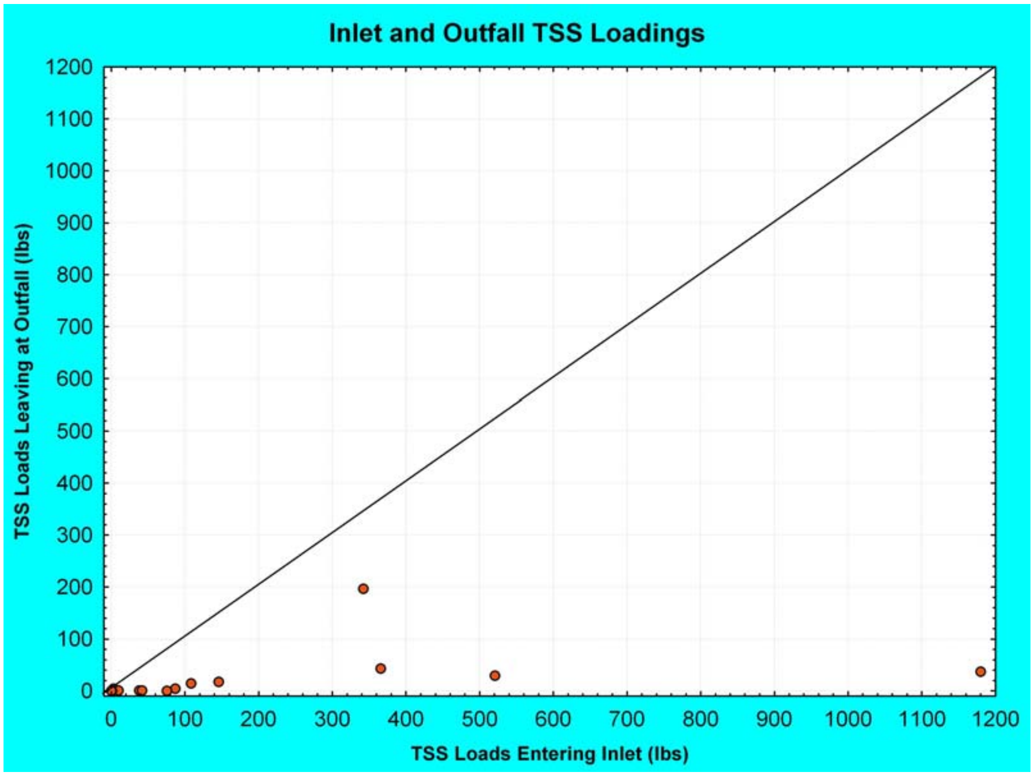

Figure 3.12. TSS Loadings Entering Versus Leaving for Three Sediment and Erosion Control Structures in Clarksburg (Automated Sampling Data).

Clarksburg Town Center Sediment Basin #3 (Clarksburg SPA)

Clarksburg Town Center Sediment Basin #3 consists of two forebays and a main cell. This structure was monitored for TSS during construction of Phase II-B of Clarksburg Town Center, and received drainage from an area converted from agricultural to residential land use. Mass grading was initiated in late 2003, but TSS sampling did not begin until March 2005. This sediment basin has been converted to a SWM BMP, but it is not yet online. The last sampled storm prior to conversion was collected in March 2007.

Sampling difficulties were encountered that limited the dataset. In addition to instrument malfunctions, there were difficulties determining the necessary sampling locations to account for all stormwater inputs, low flow at some inlet pipes, and difficulties accounting for flow caused by groundwater. Sediment Basin #3 intercepted groundwater, which made it difficult to determine when all the runoff from a storm event was discharged. Staff conducting the monitoring decided to measure flows leaving the structure for a consistent time span. Even though the trap was designed to dewater to the lowest perforation on the dewatering device within approximately 48 hours following a storm event, flows continued up to twenty days after a rain event. In order to collect representative storm data, monitoring staff decided that sampling at the outfall would continue until 48 hours after the end of a rain event (Jones 2007).

TSS loading data are available for eight storms for Sediment Basin #3 (Table 3.1). The data from the eight storms indicate that the structure was consistently effective at trapping sediment, but was somewhat variable in performance. The lowest efficiency was reported at 43% and, on average, the structure reduced TSS loadings by 87%. Continued flow of groundwater through the structure slowly carried enough sediment to reduce the efficiency of the structure as can be seen in the 2005 data from three sampling events where monitoring was extended to account for continuous flow from the outlet (Table 3.2). Comparing the data in Table 3.2 to the data from the same dates in Table 3.1 shows a decrease in efficiency as monitoring was extended. Therefore, results for this structure should be used cautiously when interpreting the efficiency of the structure and the TSS loadings delivered to the stream from individual storms.

Table 3.1. Clarksburg Town Center Phase II-B Sediment Basin #3 Sediment Loadings.

Date of Event	Storm Characteristics			Discharge Volume (cf)		TSS Loading (lbs)		TSS Reduction
	Total (in)	Duration (hrs)	Return Interval	Inlets (combined, sum)	Outfall	Inlets	Outfall	
4/30/2005	0.82	22.25	< 1 yr	65,488.4	57,292.9	520.7	29.4	94%
5/19/2005	1.04	14.15	< 1 yr	43,992.0	35,813.4	366	43.2	88%
5/23/2005	0.84	29.25	< 1 yr	57,025.0	38,853.0	146	17.5	88%
5/11/2006	1.76	13	< 1 yr	24,563.4	66,577.8	342.1	196.7	43%
6/1/2006	0.45	9	< 1 yr	64,989.2	78,096.6	1180	37.1	97%
9/1/2006	1.95	31.58	< 1 yr	114,413.1	114,048.6	3.1	4.4	-44% **
12/22/2006	1.30	15.67	< 1 yr	62,710.9	16,393.2	108.4	14.3	87%
3/15/2007	2.09	47	< 1 yr	127,003.4	83,313.6	87.2	4.3	95%
					Mean	**344.2**	**43.4**	**87%**

** - Outlier – The negative TSS reduction during the September 1, 2006, storm was most likely due to low TSS concentrations in the runoff and resuspension of sediment in the trap.

Table 3.2. Total Suspended Solids Loadings and Percent Difference Observed During Extended Sampling at Clarksburg Town Center Phase II-B Sediment Basin #3.

Date of Event	Rain (in.)	Rainfall Duration (hours)	Return Interval	Duration of Extended Outfall Sampling (hours)	TSS Loading (lbs)		TSS Reduction
					Inlets	Outfall Extended Sampling	
4/30/2005	0.82	22.25	< 1 yr	339.6	520.7	89	83%
5/19/2005	1.04	14.15	< 1 yr	88.75	366	68.5	81%
5/23/2005	0.84	29.25	< 1 yr	170.5	146	34.3	77%

Gateway Commons Sediment Basin #2 (Clarksburg SPA)

Monitoring for TSS at Sediment Basin #2, a dual cell structure, was conducted from April through October 2006 and September 2008 through January 2009. Monitoring commenced over one year after the start of construction. All storm samples were collected after roads and storm sewers were in place, and the site was stabilized on February 15, 2006. Monitoring was initially delayed because of the need to finalize the basin configuration and to direct overland flows to the basin. Construction activities stopped in March 2006 and did not begin again until September 2008.

The data available from a total of seven storm events show low TSS loadings entering the structure (Table 3.3., Station #1) and little sediment leaving the structure (Table 3.3, Station #3), resulting in very high removal efficiency. There are several instances where the automated samplers were not capturing flow. A lack of flow leaving the first cell suggests that all runoff was infiltrating or being retained within the first cell and not entering the second cell. Similarly, if automated samplers at the outfall of the lower cell were not collecting any samples, very little, if any flow was leaving the structure and the structure was functioning well. Discharge volume measurements at Station #3 show that the lower cell tends to trap any excess water released from the upper cell (Table 3.3).

Table 3.3. Gateway Commons Sediment Basin #2 Sediment Loadings.

Date of Event	**Storm Characteristics**			**TSS Loading (lbs)**			**TSS Reduction (%)**		**Discharge Volume (CF)**		
	Total (in)	**Duration (hours)**	**Return Interval**	**Station #1** (Inflow; Upstream of Upper Cell)	**Station #2** (Between upper & lower cell)	**Station #3** (Outfall of Lower Cell)	**Upper Cell** (#1 to #2)	**Overall** (In vs. Out; #1 to #3)	**Station #1**	**Station #2**	**Station #3**
04/21/ 2006	1.11	40.67	< 1 yr	18.0	3.4	n.f.	81%	100%	127,646.4	4,598.4	n.f.
05/11/ 2006	1.76	13	< 1 yr	10.6	0.8	n.f.	92%	100%	37,628.4	3,286.5	n.f.
09/01/ 2006	1.95	31.58	< 1 yr	0.3	n.f.	n.f.	100%	100%	21,450.6	n.f.	n.f.
09/28/ 2006	0.79	5.5	< 1 yr	2.4	n.f.	n.f.	100%	100%	6,084.6	n.f.	n.f.
09/25/ 2008	1.88	62.25	< 1 yr	38.3	9.9	0.5	74%	99%	48,152.4	5,161.2	492.6
12/16/ 2008	0.64	19.1	< 1 yr	9.9	37.1	0.5	-273%	95%	43,015.4	19,251.2	1,002.7
01/06/ 2009	1.5	24.92	< 1 yr	42.0	2.0	0.4	95%	99%	83,768.2	4,544.6	906.0
Average							**38%**	**99%**			
n.f. = no flow (no flow collected). Where no flow left the structure TSS reductions would be 100%.											

The negative TSS load removal efficiency calculated from the December 2008 storm in the upper cell may be the result of low TSS loads entering the upper cell of the structure. During this event, some stormwater bypassed the cells when the runoff reached the *flow splitter* above Station #1. Any runoff redirected by the flow splitter re-enters the treatment system below Station #3. The remaining runoff entered the upper cell and caused resuspension of the sediment already in the basin, resulting in a higher TSS load leaving the upper cell than entering. However, the sample collected at the outfall of the lower cell reveals that this second cell successfully reduced the additional sediment that was flushed from the first cell. Similar to the other monitored storm events, the overall removal efficiency is better than the TSS load reduction of one cell alone. Loading data between Station #1 and Station #3 were found to be statistically significant (Jones 2009a). See Technical Appendix for a description of the statistical analysis.

Redundant cells are effective in reducing stormwater runoff and decreasing loadings.

Stringtown Road Extension #3 (Clarksburg SPA)

Sediment Basin #3 is an oversized single cell basin located in the northwestern corner of the Gateway Commons development, adjacent to the Stringtown Road – Gateway Center Drive junction. The basin treats 12.9 acres of runoff from Stringtown Road Extension and Gateway Commons. It then discharges to an existing off-site stormwater management pond to the west of Gateway Center Drive before the stormwater reaches a tributary of Ten Mile Creek. TSS sampling at the inlet and the outfall of Sediment Basin #3 took place from September 2006 through December 2007. Construction on the Stringtown Road Extension has been completed since November 2006, but Basin #3 will not be converted to SWM until construction is completed at Gateway Commons. As of March 2008, less than 30% of Gateway Commons housing units within the drainage area of Basin #3 were under construction.

TSS loading removal efficiency for three storms at Stringtown Road Extension Basin #3 ranged from 88.80% to 99.96%, with an average removal of 94.42% (Table 3.4). The first two monitored storms did not produce measurable flow and a low flow strainer was installed prior to the third monitoring event. The high TSS load removal efficiency may be partially attributed to the reduction of flow leaving the structure due to the basin sizing. The basin has a capacity of 58,071 cubic feet (cf), which is 125% of what would normally be required in non-SPA developments. The basin was mucked out on May 30, 2006, prior to any sampling events. Due to the status of the Gateway Commons development, construction activities, and thereby sediment, entering the treatment system may have also been limited.

All storm events captured at Stringtown Road Extension were below the one year return interval. A backwater issue that occurred during the March 15, 2007, rain event suggests that performance of the basin could be diminished under larger storm events. Larger and more intense storms may cause re-suspension of existing sediment in the basin. TSS load removal capacity may also differ now that portions of the drainage area are under construction for Gateway Commons as of March 2008.

Table 3.4. Stringtown Road Extension Sediment Basin #3 Sediment Loadings.

Date of Event	Storm Characteristics			TSS Loadings (lbs)		TSS Loading Removal Efficiency	Discharge Volume (CF)	
	Total (in)	Duration (hours)	Return Interval	Inlet	Outfall		Inlet	Outfall
9/1/2006	1.95	31.58	< 1 yr	1.51	n.a.	n.a.	7,852	1,402
9/28/2006	0.79	5.5	< 1 yr	7.87	n.a.	n.a.	1,612	414
3/15/2007 *	2.09	47	< 1 yr	**	2.09	**	**	10,872
4/11/2007 *	0.84	7.42	< 1 yr	1.05	0.12	88.80%	2,917	655
6/28/2007 *	0.79	0.67	< 1 yr	75.48	0.03	99.96%	3,457	269
12/2/2007 *	0.57	8.33	< 1 yr	0.38	0.02	94.50%	1,843	811
Average						**94.42%**		

* Low flow strainer installed to facilitate sampling at the outfall (Jones 2008a).
** Upstream discharge for 3/15/2007 event is inaccurate due to backwater in pipe. No loading could be calculated.

Flow-weighted Composite Sampling at Other Projects

Two projects required to conduct automated sampling of S&EC basins failed to collect data in 2008. Insufficient water depths at the sampling locations prevented collection of useable data at Greenway Village. A weir was obtained and installed in May 2009 to concentrate the flow and create the proper conditions for sampling. Lack of payment to the monitoring consultant by the developer prevented data acquisition for Woodcrest. DEP has been working with the developer to remedy this situation and get the site back in compliance.

It is anticipated that construction on the approximately 535-acre Cabin Branch development will begin in 2010. This project will conduct automated flow-weighted composite sampling at the largest active sediment basin.

3.4 Stormwater Management (SWM) BMP Monitoring

Post construction BMP monitoring evaluates the efficiency of SWM BMPs in reducing pollutant loadings and the effectiveness of BMPs at achieving site performance goals. The BMPs in the SPAs are configured in redundant treatment trains to optimize performance. A diagram of a labeled SPA site plan with redundant SWM BMPs is provided in the Technical Appendix. Post construction monitoring cannot begin until the construction on the property is complete, the site is stabilized, and the S&EC structures are converted to SWM structures. As of 2008, post-construction monitoring cannot begin until after a post-construction stream monitoring bond is posted and a permit is issued (Section 2.1.3). The permitting process begins once the SWM structures are inspected and approved. Monitoring can extend up to five years on large projects.

Data is collected by using automated samplers to collect flow-weighted composite storm samples. Although not as difficult as sediment control structures, monitoring SWM structures is quite challenging. Ponding or backwater issues, equipment failure, or flow measurement distortion have continued to limit the amount of available flow-weighted composite data that can be evaluated for BMP efficiency of SWM structures.

Three projects monitoring SWM BMPs fulfilled their monitoring requirements and another property began post-construction monitoring in 2008. A full assessment is provided for Willow Oaks (Piney Branch SPA), Cloverly Safeway, and Snider's Estates (Upper Paint Branch SPA) and presented under the SWM BMP technology monitored. Clarksburg Ridge (Clarksburg SPA) began sampling of a surface sand filter treatment train in 2008, but has experienced sampling difficulties. An additional SWM monitoring project in Clarksburg, Running Brook, has failed to meet monitoring requirements and no useful flow-weighted data has been collected at this point. Additional information, figures, and data for Willow Oaks, Snider's Estates, and Cloverly Safeway are provided in the Technical Appendix.

3.4.1 Surface Sand Filter Results

Background

A surface sand filter is a media filter. It is best-suited for managing the high concentration of pollutants in the volume generated by the first inch of rain (also known as the first flush). The Montgomery County Sand Filter design is essentially a shallow, dry stormwater management facility which incorporates a sand filter and an underdrain. Pre-treatment is provided by a grass filter strip or other structural means (MCDPS 2007).

The sand filters are designed to include a recharge area beneath the filter medium and underdrain pipe to promote infiltration into suitable soils. The water remaining in the structure below the level of the underdrain pipe will percolate into underlying soils with suitable infiltration rates. SPA performance goals encourage the use of infiltration to reduce storm flow runoff and recharge groundwater to help maintain stream base flows.

Sand filters have a range of removal efficiencies and are generally effective at removing total suspended solids, with removal efficiencies of 66% to 95% reported in the literature (Technical Appendix).

Willow Oaks (Piney Branch SPA)

Willow Oaks is an 8 acre, 14 single family lot cluster option development located on the eastside of Travilah Road, opposite Stonebridge View Drive. Prior to development, the site was forested; following development 33% of the site (approximately 2.4 acres) is in conservation easements and 6.9 acres of the development is within the Piney Branch SPA.

The stormwater management for the SPA portion of the development provides treatment for road surface (Unicorn Way) and portions of residential lots. Quantity treatment is provided through a downstream existing SWM pond in the pre-SPA Willows of Potomac subdivision (Pond 2). This pond provides detention of the two-year storm with a pre-developed release rate. Quality control is provided by a treatment train consisting of two surface sand filters in series (Technical Appendix). Vegetated filter strips provide pretreatment for the surface sand filters.

Monitoring of metals, nutrients, and suspended solids was required at three locations: 1) upstream of the first sand filter, after the vegetated strips; 2) after exiting the upper sand filter; and 3) at the outlet of the second sand filter cell. Automated samplers were used to collect storm samples four times per year to assess the efficiency of the BMP at reducing loadings of selected pollutants. Sampling began in July 2005. Thirteen storms were captured and sampling concluded in March 2008. See Technical Appendix for BMP data and storm characteristics.

Median BMP efficiency for all monitored parameters was greater than 69% (Fig. 3.13), and is consistent with literature reported values. Maximum removal efficiency was 99.6%, but there are other instances where removal was as low as 20.2%. In some cases more of a pollutant was leaving the structures than entering (Fig. 3.13; Copper). Cadmium, lead, and nitrite were not provided for this analysis due to a prevalence of below detectable limits.

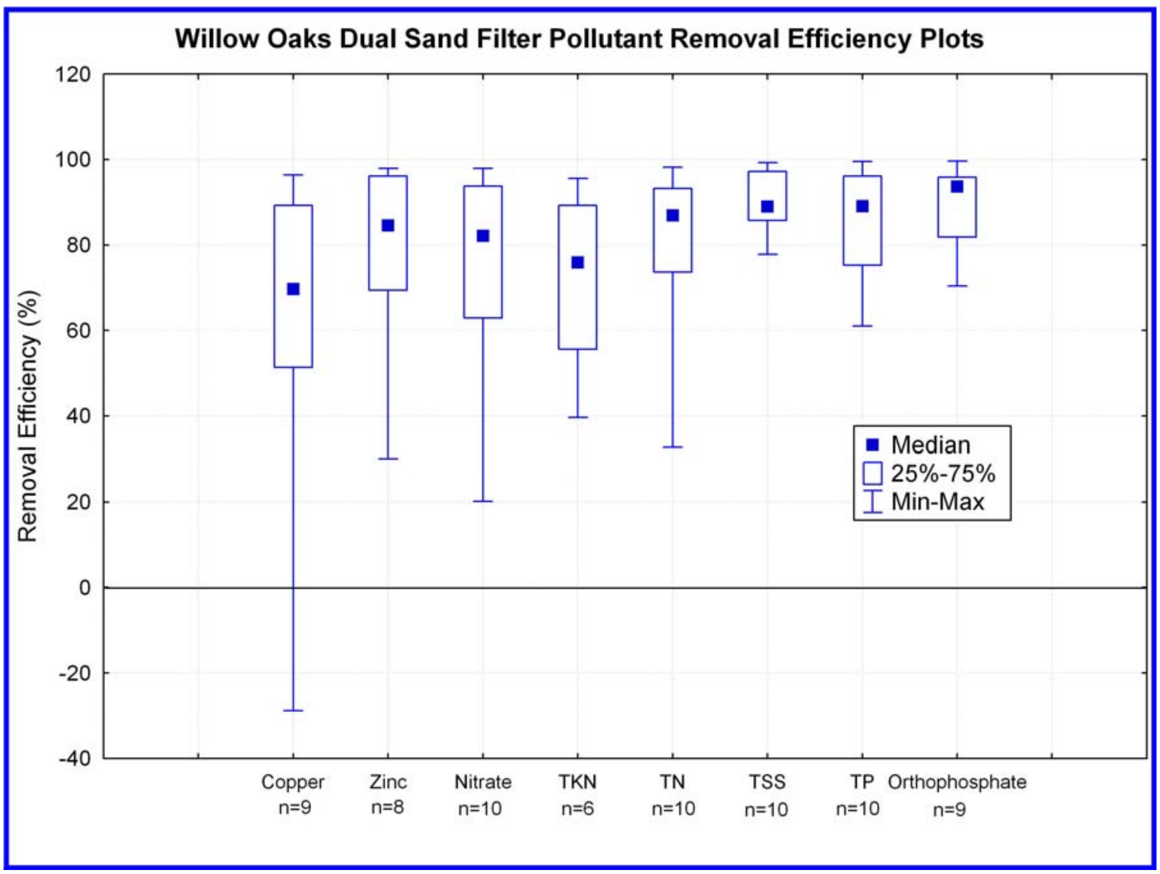

Figure 3.13. Willow Oaks BMP Pollutant Load Reductions. Load Reductions were Calculated by Examining the Total Load Entering the System (Two Sand Filters in Series) With the Total Load Leaving.

The two sand filters in series were efficient at removing orthophosphate and total suspended sediment loadings. Orthophosphate achieved the highest median removal efficiency of 93.7% in comparison to other parameters. The median total suspended solids performance efficiency was 89.0%, and there was the smallest range between the maximum and minimum efficiencies of all constituents measured (Fig. 3.13). A significant downward trend in TSS concentrations over time was also found, suggesting that either the BMP performance was improving over time for this parameter or that less sediment was entering the system. Lower concentrations of sediment entering the BMPs could be because the Willow Oaks development became more stable over time.

The two sand filters in series reduced zinc, TSS, nitrate, total nitrogen, orthophosphate, and total phosphorus loadings significantly. See technical appendix for statistical analysis information.

Two surface sand filters in series were more effective than the use of one structure alone.

The monitored SWM BMP reduced total Kjeldahl nitrogen (TKN) and total nitrogen when the preceding dry time was the greatest, meaning it did not reduce loadings as well when the sand filters were already retaining stormwater from a previous storm event. The amount of precipitation also influenced loadings of orthophosphate, TKN, and total nitrogen leaving the second sand filter in the series (Jones 2008b). A discussion of statistical significance (Jones 2009b) is provided in the Technical Appendix.

The series of vegetated filter strips and two surface sand filters achieved high pollutant removal efficiency success for the evaluated storm events. The SWM BMP success was largely attributable to the design of the surface sand filters to promote infiltration and retain runoff in the sand layers. All storms evaluated for pollutant loading reduction were smaller than one-year storm events (Table 3.5). Larger precipitation events could influence BMP performance, particularly if there is a short duration between storms.

Table 3.5. Storm Event Data for the Ten Storms Used to Evaluate Willow Oaks BMP Pollutant Load Reductions Efficiency.

Storm Date	Rainfall Quantity (in)	Rain Duration (hr)	Return Interval (yr)	Preceding dry time before storm event (hr)	Total Flow Volume (m^3)		
					Station #1 (Entrance to upper sand filter)	Station #2 (Exit of upper sand filter, entrance to lower)	Station #3 (Outlet of lower sand filter)
1/22/2006	0.8	14.5	< 1	108.25	2,737	410	293
4/21/2006	1.51	26.75	< 1	104.5	2,649	2,984*	269
10/17/2006	0.74	9.0	< 1	116.5	1,161	73	37
11/16/2006	1.60	7.75	< 1	72.0	3,887	8,337*	99
4/11/2007	0.72	7.25	< 1	105.0	723	57	85
12/15/2007	0.76	14.5	< 1	36.17	1972	117	373

2/1/2008	1.30	7.92	< 1	64.17	861	4202*	638
3/4/2008	2.11	13.92	< 1	168.17	616	869*	228
3/7/2008	0.67	27.5	< 1	54.75	338	59	153
3/19/2008	0.56	13.83	< 1	50.67	229	40	75

* Inaccurate flow rate measurement due to ponding in weir (Station #2)

The Willow Oaks subdivision drains to County biological monitoring station WBPB203A. This station receives the majority of its drainage from the Willows of Potomac, a large pre-SPA development. A discussion of SPA stream conditions and benthic macroinvertebrate community trends are presented in Section 5.

Snider's Estates (Upper Paint Branch SPA)

The 8.1 acre Snider's Estates subdivision on Snider Lane, between New Hampshire Avenue and Good Hope Road, consists of six residential lots and a 0.72-acre parcel for SWM. About 50% of the site is medium-density residential and 10% of the property is dedicated to stormwater management land use. The remainder of the property is a forest conservation easement.

SWM consists of a sand filter and two dry ponds in series. Storms greater than the one to two-year design storm overflow directly from the upstream pond (Pond 1) into the downstream pond (Pond 2).The outfall of the downstream pond (the retention structure) discharges to pasture and brush. An infiltration trench is situated up-gradient and adjacent to the downstream pond. In addition to managing on-site storm flow, the SWM structures also treat an additional 24,000 square feet of impervious area along Snider Lane (west of the site).

Monitoring examined the quantity control feature of the sand filter by evaluating whether flows were reduced to the levels predicted by the design model. The scope of the monitoring was limited due to the limited amount of development. Monitoring of continuous storm flow was conducted at a location between Pond 1 and Pond 2 (Technical Appendix).

Performance of the SWM facility was evaluated by comparing measured pond outflows with TR-20 design storm simulated events. The pond is designed to provide SWM quantity control by providing storage for a volume of water greater than that needed to control the six-month and one-year storms and to provide storage for a volume of water equivalent to that produced by the two-year rainfall event. The design model does not account for the initial filling of the sand filter and infiltration trench or the infiltration of stormwater into the soil within the SWM.

Post construction monitoring began in December 2004 and concluded in late 2007. Fifteen storms were measured and characterized (Technical Appendix). Six of these storms had return intervals greater than one year and could be compared with the TR-20 model simulated responses to test whether the pond was functioning as designed (Table 3.6).

Table 3.6. TR-20 Measured Storm Results for Peak Flow at Snider's Estates SWM Pond 1 Outlet into Pond 2.

Storm Date	Storm Rainfall (in.)	Storm Duration (hr.)	Storm Frequency (yr.)	Observed (Measured) Peak Flow Rate (CFS)	Expected (Controlled) Peak Flow Value (CFS)	Expected (Controlled) Peak Flow Range (CFS)
1/14/2005	2.0	6.8	1-2	4.6	0.2	0.1 – 0.8
7/7/2005	2.9	15.2	2	5.0	0.6	0.1 – 1.4
10/7/2005	6.1	22.5	2-5	3.6	2.8	1.8 – 4.0
6/25/2006	6.8	9.1	200	10.7	10.3	4.8 – 13.7
6/13/2007	2.0	2.1	5	0.7	0.2	0.0 – 2.5
10/24/2007	4.4	77.3	2	0.1	1.7	0.2 – 2.5

The model was variable at predicting the runoff and control of SWM facilities. Observed peak flow rates were within the expected peak flow ranges for storms greater than two-year frequency. Observed peak flow rates from one to two year frequency storms were not within the expected peak flow ranges. Factors such as a decrease in annual rainfall and accompanying extended dry periods or the growing lawns and vegetation from the residential lots could have influenced BMP performance. Measuring the peak flow at the outfall of Pond 2 would be needed to fully evaluate the effectiveness of the treatment train at retaining storm flow.

The Snider's Estates subdivision drains to County biological monitoring station PBLF202. The 8 acre Snider's Estates property is the only new SPA development in the 466 acre drainage area to PBLF202. A discussion of SPA stream conditions and benthic macroinvertebrate community trends are presented in Section 5.

3.4.2 Stormceptor® Results

Background

A Stormceptor® (hereafter "Stormceptor") is a *hydrodynamic device*. Hydrodynamic devices use the flow and direction of water to remove pollutants. The Stormceptor is designed to treat a maximum flow rate and bypass the remainder of the runoff volume. The Stormceptor slows incoming stormwater to reduce turbulence, which allows oils to rise and sediment to settle.

A study by the Massachusetts Strategic Envirotechnology Partnership (STEP 2003) that monitored two Stormceptors found that the device removed between 52% and 77% of TSS, which is lower than the 80% targeted by the manufacturer (Rinker Materials 2008). A report by the Center for Watershed Protection (RAC 2002) cited performance of

Stormceptors between 21% and 51.5% removal of TSS. More materials on the Stormceptor are provided in the Technical Appendix.

Cloverly Safeway

The Cloverly Safeway is located on New Hampshire Avenue. Part of this commercial site falls within the Upper Paint Branch SPA. BMP monitoring on this project consisted of evaluating the efficiency of a Stormceptor (model 1800) in the reduction of pollutant concentrations and loadings during storm events as well as monitoring and assessing the effluent for the presence of temperature increases. The model number denotes the capacity of the device: 1,800 U.S. Gallons.

Other BMPs in the treatment train leading to the Stormceptor consist of stormwater storage underneath a parking area and a *bioretention structure* adjacent to the southern section of the parking area.

Stormwater runoff enters the stormdrain system through three curbside inlets in the parking lot (one located at the entry from Briggs Chaney Road and the other two along Gallaudet Avenue), and from two overflow inlets sited in the bioretention facility located between Briggs Chaney Road and the parking area. Excess water from the bioretention area is piped underneath the parking area to join the direct runoff from the three curbside inlets. The runoff then enters a storage area, which consists of a network of pipes underneath the parking area. All runoff from the southern portion of the parking area passes through the bioretention area to the underground storage or flows directly to storage under higher flows. Runoff from the southeastern (rear) portion of the parking lot passes through the *oil-grit separator* and discharges to the underground storage area. Stormwater leaves the underground storage area through a *trash rack*, *regulatory weir* (control structure), and then finally to the Stormceptor before leaving the site.

The Stormceptor functions as final quality control in the treatment train. Flow-weighted samples of cadmium, copper, lead, zinc and total suspended solids, along with a *total petroleum hydrocarbon (TPH)* grab sample were collected from locations before and after stormwater passes through the structure (see Technical Appendix). Post construction monitoring of the Cloverly Safeway Stormceptor began in May 2003 and was required for five years. The last required storm of the 15 was captured in April 2008. Weather-related challenges and mechanical difficulties prevented acquisition of data for 2007 (the December 2007 storm was collected in fulfillment of 2006's requirement of three storms per year).

Pollutant concentrations entering the device so low that they were below the reportable detection limit and could not be evaluated. Methods, detection limits, and concentration and loading data for the pollutants analyzed are provided in the Technical Appendix. Three analytes – copper, zinc, and TSS – produced measurable results where loadings could be calculated. Performance of the Cloverly Safeway Stormceptor at removing copper, zinc, and TSS was highly variable and median removal efficiencies were below 20% (Fig. 3.14). The high variability may be the result of the low concentration of pollutants in the stormwater entering the device. The Stormceptor is downstream of another quality control structure in the treatment train. The bioretention structure provides quality control, using vegetation and soils to remove pollutants from the stormwater. It is possible that the bioretention area reduced pollutant concentrations to where water quality could not be improved any further.

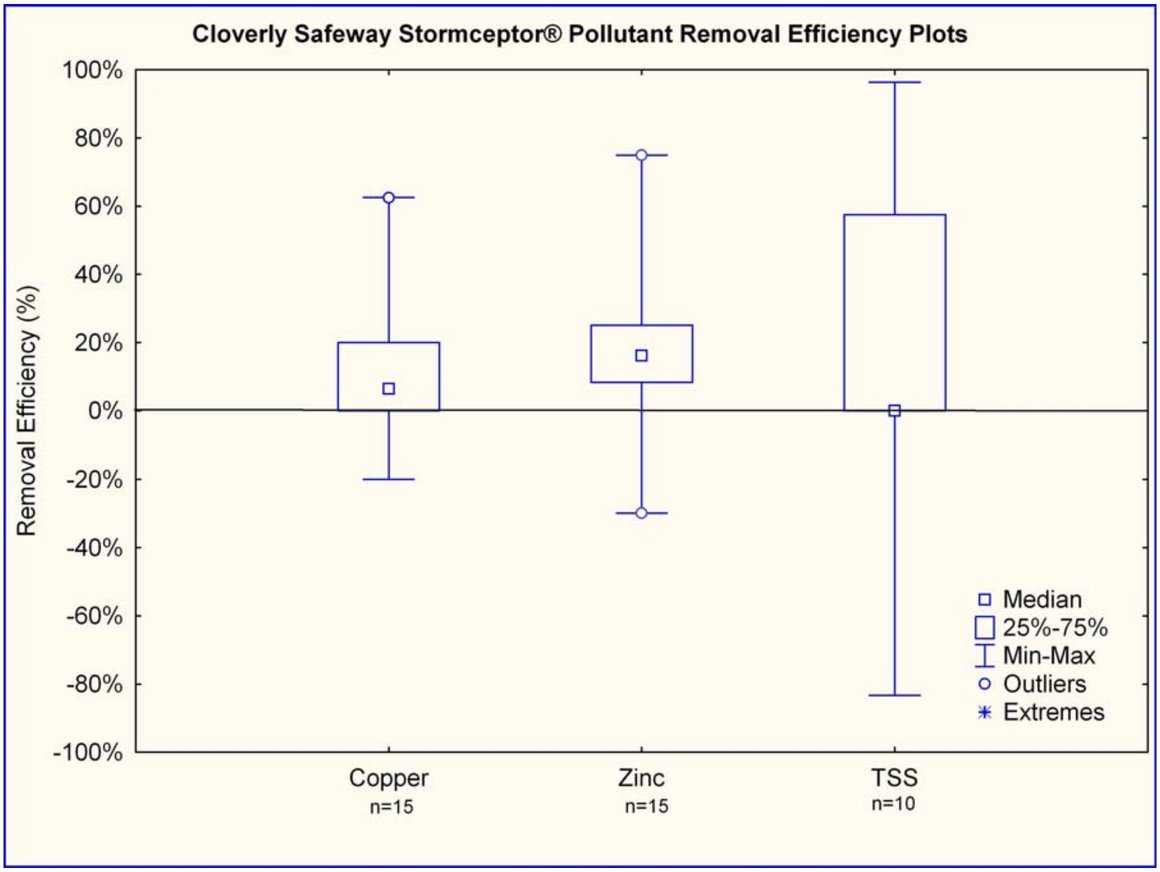

Figure 3.14. Cloverly Safeway SWM BMP Pollutant Load Reductions. Load Reductions Were Calculated by Examining the Total Load Entering the Stormceptor With the Total Load Leaving

Total suspended solids were present in much higher concentrations than copper or zinc. The ability of the Stormceptor (model 1800) to reduce TSS loadings was marginal and there was an apparent decline in performance (Fig. 3.15). The device initially reduced TSS loadings for the first four monitored storms (April 23, 2005 through November 15, 2006). However, for the remaining storms (November 22, 2006 through April 3, 2008), the loads leaving the device were equivalent to or higher than the loads entering. The performance of the device may be attributed to its age, lack of maintenance, and its placement in the treatment train. Sampling of TSS did not commence until two years after the structure was being monitored due to an oversight in the monitoring plan.

There did not appear to be a clear trend between structural performance and characteristics of the captured storm events. A similar study conducted on a Stormceptor

1800 in Minnesota receiving 1.03 acres of parking lot drainage cited an average TSS load reduction of 76% for eight storms for a one-year period (Cretex Companies, Inc. 1999; Rinker Materials 1999).

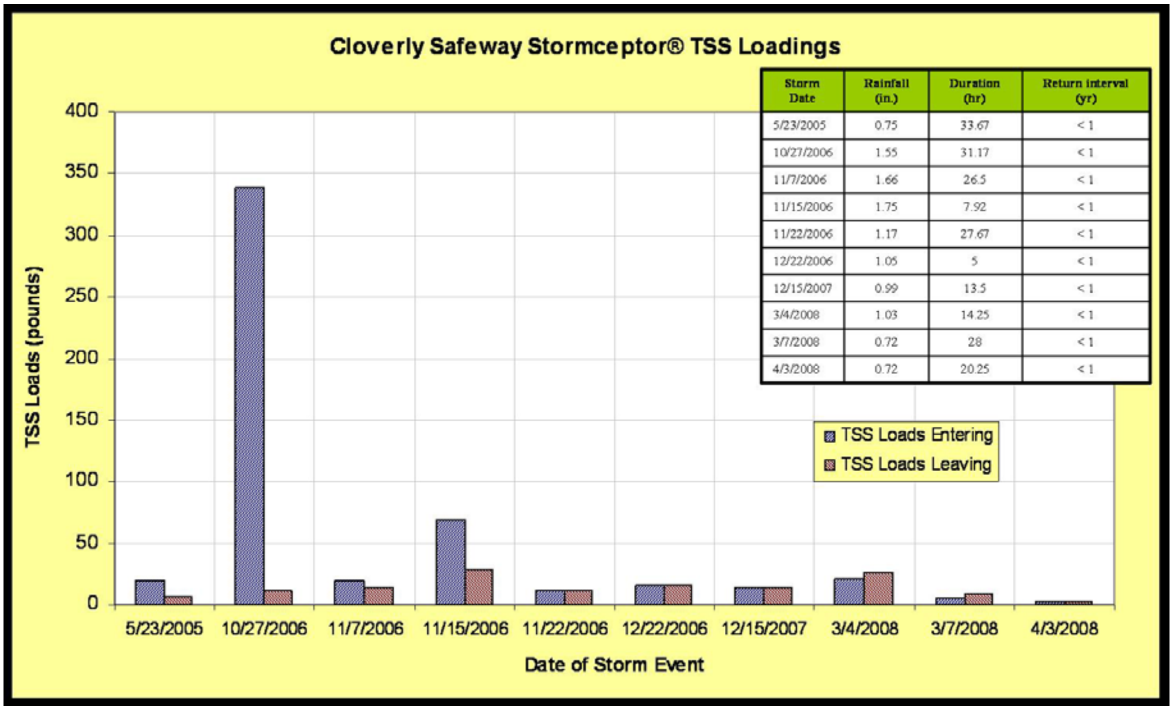

Figure 3.15. Cloverly Safeway Stormceptor TSS loads. No TSS loads are Available for Storm Events Pre-dating May 23, 2005.

Temperature was also monitored downstream of the Stormceptor in conjunction with pollutant removal efficiency (Table 3.7 (Jones2008c)). For 13 of the 15 monitored storms, runoff temperatures increased sharply between approximately three degrees (April 3, 2008) and 17 degrees (November 22, 2006) Fahrenheit at the inception of storms. Temperature response was inconclusive for the remaining two events (April 12, 2004, and November 15, 2006).

Although the Stormceptor is not designed to mitigate thermal impacts, water may be warmed as it is treated in the device. Furthermore, its location at the end of the treatment train suggests that the upstream BMPs may also be unsuccessful at reducing runoff temperature. The bioretention area is the only portion of the treatment train promoting infiltration and an opportunity for the temperature of the stormwater to be reduced as it enters the ground. Portions of the runoff also bypass this area during high flows or enter the underground storage area directly. It is likely that the stormwater is warming on the paved surfaces such as the Safeway's rooftop and parking areas and remaining warm as it collects in the underground storage area beneath the parking area. Higher temperature increases were generally associated with longer storm events.

Table 3.7. Temperature Increases Measured Downstream of the Cloverly Safeway Stormceptor.

Storm Date	Rainfall Quantity (in.)	Rain duration (hr)	Return interval (yr)	Preceding drying time (hr)	Temperature increase (°F)
5/9/2003	0.31	2.0	< 1	23.5	6
7/28/2003	0.69	5.92	< 1	14.83	4
4/12/2004	1.17	12.00	< 1	107	Inconclusive
9/28/2004	1.93	8.00	< 1	242.75	4
12/9/2004	0.56	7.5	< 1	38.75	5
5/23/2005	0.75	33.67	< 1	73	7
10/27/2006	1.55	31.17	< 1	159.83	11
11/7/2006	1.66	26.5	< 1	131.33	5
11/15/2006	1.75	7.92	< 1	68.92	Inconclusive
11/22/2006	1.17	27.67	< 1	140.33	17
12/22/2006	1.05	5	< 1	214.25	6
12/15/2007	0.99	13.5	< 1	42.5	11
3/4/2008	1.03	14.25	< 1	246.75	10
3/7/2008	0.72	28	< 1	54.25	4
4/3/2008	0.72	20.25	< 1	54.5	3

A portion of the Cloverly Safeway drains to County biological monitoring station PBGH108; the remainder of the property drains to outside the Upper Paint Branch SPA. The SPA development activities at Cloverly Safeway were limited to modifications to the existing commercial site (i.e., re-development of an existing commercial project and improvement to SWM treatment). A discussion of SPA stream conditions and benthic macroinvertebrate community trends are presented in Section 5.

3.5 Discussion of SPA BMP Effectiveness

3.5.1 Completed Monitoring Projects in 2008

Seven projects fulfilled monitoring requirements in 2008. These completed projects allow the evaluation of onsite conditions throughout the development process. Changes from baseline conditions and impacts from development were identified at two of these projects: All Souls Cemetery and the Timbercreek development. Post-construction groundwater levels were reduced at Timbercreek, suggesting that performance goals of maintaining base flows and groundwater recharge may not have been achieved. Changes in the shape of the stream channel were observed at All Souls Cemetery in response to construction activities. Changes to the natural flow regime can impact aquatic life by making stream habitat and water quality unsuitable. Monitoring of biological communities is used to further assess development impacts (Section 5).

3.5.2 SWM BMP Pollutant Removal Efficiency Monitoring at Completed Projects

The 2008 annual report marks the first time where completed projects were conducting SWM BMP pollutant removal efficiency monitoring. The SWM BMPs monitored – a dual surface sand filter and a Stormceptor – showed variable performance, largely due to the location of the BMPs in the treatment train and maintenance of the structures. Overall removal efficiency for the Willow Oaks dual sand filters was high and consistent with literature values, suggesting that the performance goal of minimizing pollutant loadings was achieved. It was also determined that the redundancy of two surface sand filters in series was more effective than the use of one structure alone and that the pre-treatment using vegetated filter strips was also an important component in enhancing BMP performance and mitigating impacts to receiving streams.

The use of treatment trains and redundancy enhanced BMP performance at a small residential community, Willow Oaks, in Piney Branch.

The Cloverly Safeway Stormceptor, on the other hand, showed declining and overall poor performance at removing TSS. This device was not located in the optimum location of the treatment train and the SWM BMPs were placed in a now outdated configuration. The Cloverly Safeway Stormceptor is located at the end of the treatment train; Stormceptors and other hydrodynamic devices work best as pre-treatment devices. With the exception of TSS, all other monitored pollutants were consistently observed in such low concentrations that they could not be measured. This suggests that other features in the treatment train, such as the infiltration trench, were reducing pollutant concentrations and successfully treating stormwater.

The placement of certain types of structures within a treatment train is important for treating stormwater and enhancing overall BMP efficiency.

SWM BMP monitoring at three small (<10 acre) SPA properties was completed in 2008. More data is anticipated over the next few years from portions of SPAs where the majority of the subwatershed monitoring area is undergoing SPA development. Clarksburg Ridge (Clarksburg SPA), transitioned to post-construction monitoring in 2008, and has commenced collection of automated flow-weighted composite samples at a SWM BMP. Parkside (Clarksburg SPA), Briarcliff Meadows (Paint Branch), and Traville (Piney Branch) will begin post construction monitoring in 2009 and are all conducting structural monitoring. Other development areas in Clarksburg (Clarksburg Town Center, Clarksburg Village, Greenway Village, and Summerfield Crossing) also have portions where drainage areas to S&EC are approaching conversion to SWM.

3.5.3 S&EC Monitoring During Construction

No new construction monitoring began in 2008, but monitoring of TSS at eight projects was ongoing. Grab sampling of TSS at S&EC structures continued to demonstrate that higher outfall concentrations are observed late in the construction process where less exposed earth is present on a site. Under these conditions, more sediment may be leaving the structure than entering in stormwater due to the resuspension of fine clays and silts already accumulated in the structure control basin. Additionally, the concentration of pollutants in runoff (i.e. how dirty it is) can influence the actual pollutant removal percentages. If the concentration is near an *irreducible level*, such that it is near or below a detectable limit, a low or negative removal percentage can be recorded (Schueler 2000).

In response, the County is investigating if S&EC BMPs can be converted to SWM BMPs once the majority of the drainage area to the individual treatment structure is complete. The earlier conversion to SWM should result in less sediment discharging to receiving streams and better treatment of stormwater discharge and removal of other pollutants by the SWM BMPs. Assessment is made on a case-by-case basis to determine if the remaining disturbance from construction can be controlled by super silt fencing alone or another means of S&EC. DPS and DEP have been working with the developers, project engineers and monitoring consultants to assess which basins meet these conditions.

Automated flow-weighted composite sampling, which better represents pollutant concentrations over the duration of a storm event and the pollutant loadings delivered to receiving streams, showed that TSS was being reduced at the three S&EC basins monitored in Clarksburg. The average TSS load reductions for Gateway Commons and Stringtown Road Extension are higher than the average 87% removal observed at Clarksburg Town Center.

There are very little data and scientific literature available for evaluating the efficiency of S&EC basins at capturing total suspended solids. More research is needed to reveal factors that cause S&EC or SWM structures to function well or poorly. Several variables have been identified as sources of disparity (CWP 2007), including:

- the amount and type of sediment disturbing activities occurring at the site at the time of sampling;
- the number of storms sampled and the characteristics of each (i.e. rainfall and accumulation, duration, flow rate, particle size of each);
- the monitoring technique employed;
- the internal geometry and storage volume and design features of the structure;
- the size and land use of the contributing *catchment*.

3.5.4 Conclusion

Performance goals established for each development project as part of the Water Quality Plan should protect natural features. However, because the S&EC and SWM structures have traditionally been sited after building locations and other infrastructure, some approved land development projects within SPAs have not protected the natural features necessary to sustain important aquatic resources.

If S&EC and SWM structures are not considered in the early stages of preparing a development plan, opportunities for sustainability are not fully achieved and resources may not be fully protected.

By not siting BMPs early in the planning process, the S&EC and SWM structures are typically pushed to the perimeter of the site. In some cases, this has resulted in locating S&EC and SWM structures in areas with high water tables, thereby diminishing their performance, as was the case in Clarksburg Town Center. Recognizing this conflict, DPS, DEP, and M-NCPPC work closely with the developers and engineers to determine where structures should be sited on new development plans. Close coordination between agencies also assists with designing structures so that they can be easily monitored.

DEP and DPS continue to improve consultant success at collecting automated flow-weighted composite samples at S&EC and SWM structures and to help minimize impacts through the development process. Beginning in 2008, monitoring consultants were required to submit quarterly progress reports detailing whether monitoring is on schedule and what problems have been encountered. DEP and DPS have also continued to promote meetings and planning prior to the commencement of monitoring. In doing so, sampling error is being reduced.

Evaluating BMP efficiency by presenting percent removal is one important assessment tool, but efficiency alone does not provide the entire picture to how well a BMP is performing. Measuring changes to stream geometry, habitat, and chemistry (Section 4), and ultimately the biological community (Section 5) must also be examined as indicators of BMP effectiveness in protecting water quality.

With these factors in mind, great care should be taken, not just when examining the County's results alone, but when trying to make comparisons between BMPs employed locally and nationally.

With the exception of the Clarksburg SPA, all the other SPAs were fairly well-developed prior to being adopted as a SPA, making it difficult to separate the effects of additional development from those areas already developed. Ultimately, a conclusive evaluation of the effects of development cannot be completed until the watershed is built out or almost built out.

The evolution of development in Clarksburg, from an undeveloped, rural environment to a dense suburban/urban environment, make it a perfect test site to evaluate the ability of structural BMPs to protect water quality.

4. Stream Characteristics

Section 4 continues and builds on the collaborative work reported in the 2007 SPA Annual Report. For ten years, the County has reported on changes to biological stream conditions as a cost effective method to document the cumulative impacts occurring in SPA streams. Beginning in 2007, information on a comprehensive ecological monitoring and assessment approach has been presented to link changes in land use, stream hydrology, *stream morphology*, and habitat to changes in biological stream conditions. Applying an extensive ecological monitoring and assessment approach across all SPA watersheds is beyond the resources of the County. Recognizing this, the County formed an integrated monitoring partnership to study the changes that will occur in the Clarksburg Master Plan SPA (Section 1.2.2).

The partnership of Government agencies and universities has concentrated their resources on Clarksburg because:

- **of the ability to evaluate the effects of development on an undeveloped landscape.**
- **the level of development activity is greatest.**
- **the suite of representative BMPs to monitor is the most diverse.**
- **long term monitoring resources enable the most intensive and effective monitoring to evaluate changes in hydrology and morphology**

Results from this effort will be used to evaluate which BMP types are the most and least effective and to evaluate if engineered solutions alone can minimize the impacts of development to stream systems. Information can be used for new development activities in the other SPAs and elsewhere throughout the County. The monitoring effort also addresses the Clarksburg Stage 4 monitoring requirements.

As described in Section 1.2.2, a Before, After, Control, Impact design, or *paired catchment (watershed) design* (Farahmand et al. 2007), is used in the Clarksburg Study Area. The following subsections present information on landscape changes, hydrology, geomorphology, water quality, and habitat.

4.1 Landscape Changes in the Newcut Road Area of Clarksburg

Light Detection and Ranging (LiDAR) is a remote sensing method used to collect topographic elevation information at very high resolutions (with a vertical precision of six inches or less). LiDAR is recorded via aircraft-mounted lasers capable of recording 2,000 to 5,000 elevation measurements per second. The resulting imagery is much more precise than that of conventional aerial photography (NOAA 1999).

High resolution LiDAR imagery was flown by the U.S. Environmental Protection Agency, Landscape Ecology Branch (U.S. EPA LEB) for the first areas developed in the Newcut Road neighborhood. These areas are the neighboring properties of Greenway Village (Phases 1 to 4), and Clarksburg Village (Phases 1 and 2). In Figure 4.1, Greenway Village is on the right of the image, and Clarksburg Village is on the left. An unnamed *headwater stream* divides the developments. LiDAR was successfully taken in 2002, 2004 and 2007 by U.S. EPA LEB (MCDEP 2009). The 2002 and 2007 images are reproduced in this report (Figs. 4.1, and 4.2). LiDAR photography was done by the County in 2008 (Fig. 4.3).

The 2002 coverage (Fig. 4.1) recorded pre-construction topography of the area. Before construction activities began, the landscape consisted of gently to moderate rolling slopes and land use was predominantly farmland. The small headwater stream draining this area is identified near the bottom of the image. This stream, running between Greenway and Clarksburg Village, has a stream gage to record changes in stream flow. Four areas were established to track changes in stream morphology over time (See Section 4.2.2 for Study Design and Data Collection).

Springs and *seeps* critical to maintaining the natural flow of this stream system are identified in the image. An *ephemeral stream* tributary begins on the east (right) side of the image. Surface runoff would be conveyed into the stream through natural drainages and ephemeral stream channels. Groundwater recharge would be conveyed through the existing springs and seeps to maintain the base flow of the stream. The pre-existing stream valley can easily be seen. Overall imperviousness was low, allowing for stormwater infiltration into the ground.

The LiDAR images taken in 2007 (Fig. 4.2) and 2008 (Fig. 4.3) document changes that occurred to the topography and natural drainage patterns from the cut and fill required to bring the site into leveled and approved grades for lots, roads, and utilities. The road grade requirements of 4% maximum slope directly influence the cut and fill necessary to balance onsite excavation and avoid the cost of importing soil. This massive movement of soil has lasting effects on the water quality due to changes in the basic flow regime of the stream and groundwater (CWP 2003; Konrad and Booth 2005).

Distinct cut lines along the *limits of disturbance* document the new elevations graded into the development. The rolling topography was smoothed and leveled, altering the natural drainage patterns. Newly installed S&EC BMPs can be seen installed at the lower elevations of the new topography with some of the BMPs sited at the heads of springs and seeps. Seeps and springs in these areas have essentially been eliminated. The ephemeral stream, on the east side of the image, has nearly been eliminated through the cut and fill activity here.

Final grades can be seen throughout the site as the rolling topography has been cut, graded, smoothed, and leveled. Snowden Farm Parkway, a major connecting road, is seen in the middle of the image, bordering the headwater stream for much of its length. Grading for the parkway and S&EC BMPs bisect the natural drainage patterns on the left side of the image, impacting the springs, seeps, and recharge areas on this side of the stream. The toe of the fill required for the Parkway is seen very close to the headwater stream. Newly-defined channels across the floodplain from the S&EC BMPs are also shown in the 2007 and 2008 images.

In this portion of the Newcut Road Neighborhood:

- **Natural drainage patterns have been eliminated.**
- **Runoff from the new impervious surfaces is redirected into the stormdrain system.**
- **Overall topography, natural drainage patterns, and natural infiltration have been altered due to the cut and fill requirements necessary to meet the density requirements of these neighborhoods**
- **Most of the stormwater runoff is now diverted into stormwater inlets and drains rather than infiltrating into the ground over a wide area.**

Overall cut and fill differences are readily seen in Figure 4.4. Elevation differences are derived from the 2007 LiDAR imagery. Black and red areas are cut and the brown areas are fill. Black areas have been cut between 4 to 100 feet. Red areas have been cut 2 to 4 feet. Brown areas have been filled from 4 to 100 feet. Finer levels of elevation changes can be measured, but depiction of the finer elevation changes would be difficult to clearly show in this report. Final grades and imperviousness surfaces are on top of the cut and fill areas.

The development areas outside the immediate stream buffers have had their surface grades altered, surface drainage patterns diverted into stormdrains, and the imperviousness greatly increased from pre-construction levels. Point source SWM BMP structures are designed to minimize the loss of the pre-existing diffuse recharge system that once maintained these headwater streams. Engineered SWM BMPs are designed to minimize impacts to the receiving streams through redundant structures that provide both quality and quantity controls such that post-construction release rates are equivalent to pre-construction rates.

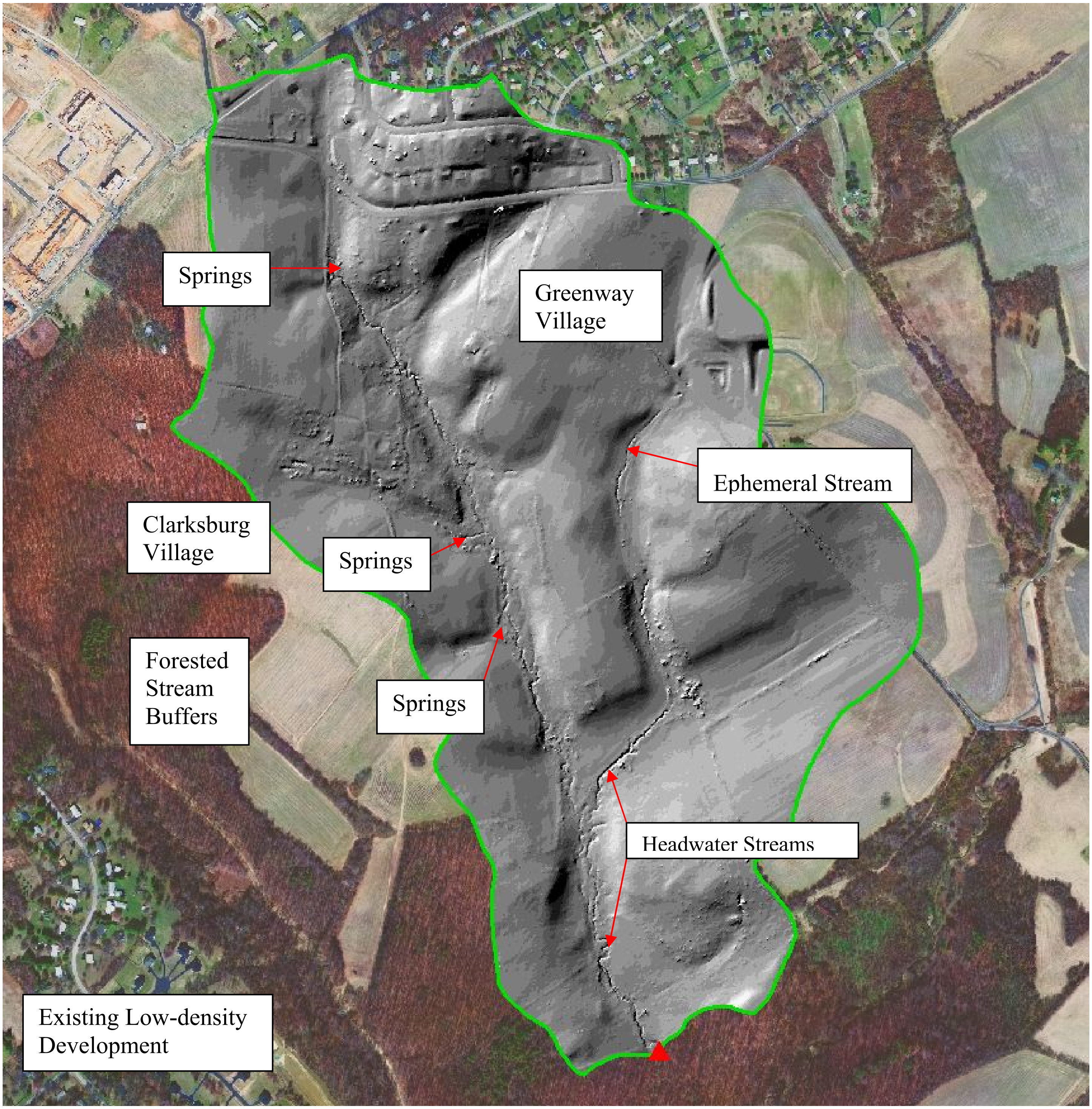

Figure 4.1. 2002 LiDAR Imagery of Newcut Road Neighborhood, Greenway Village, and Clarksburg Village (U.S. EPA LEB).

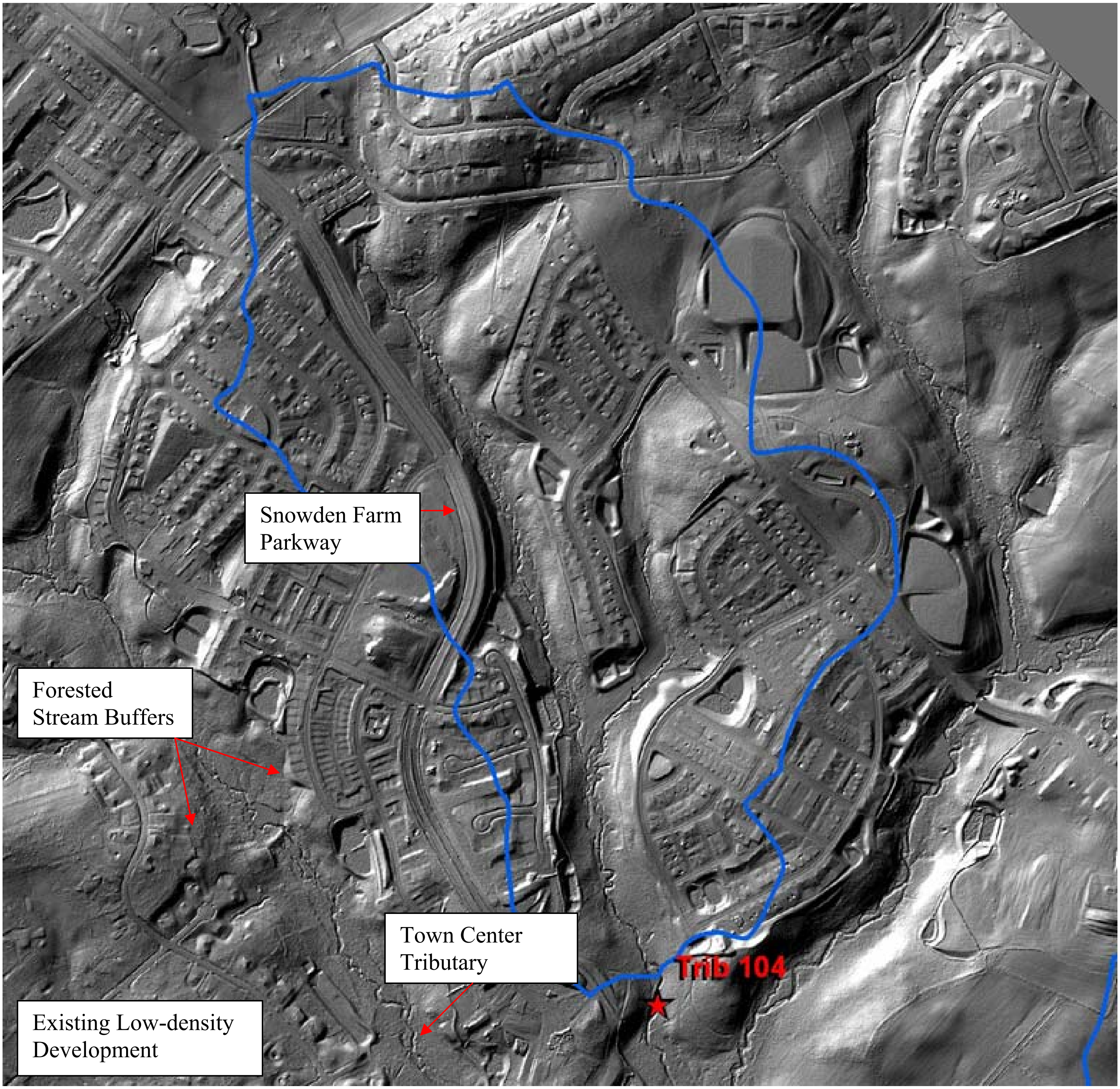

Figure 4.2. 2007 LiDAR Imagery of Newcut Road Neighborhood, Greenway Village, and Clarksburg Village (U.S. EPA LEB)

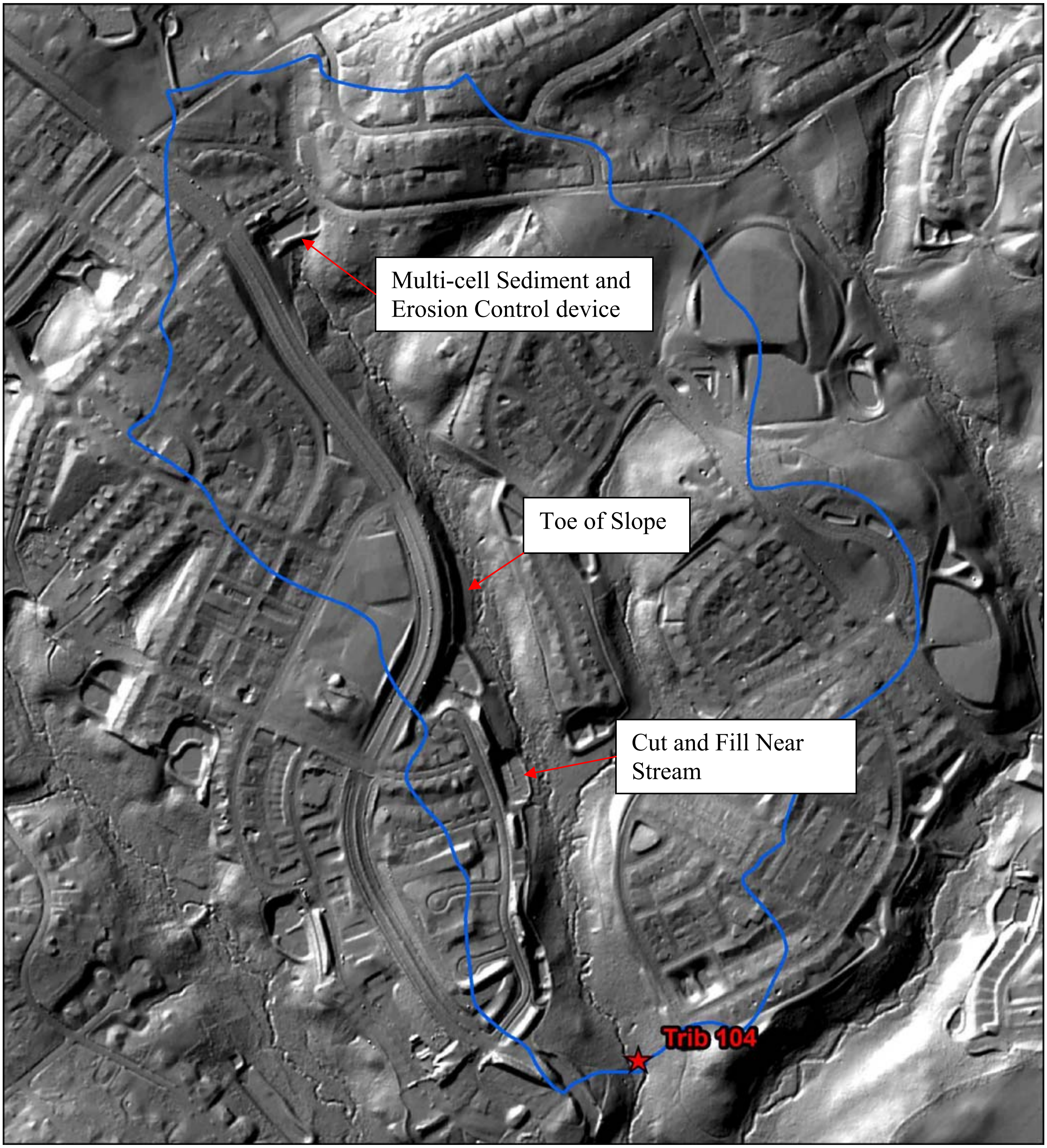

Figure 4.3. 2008 LiDAR Imagery of Newcut Road Neighborhood, Greenway Village, and Clarksburg Village (Montgomery County).

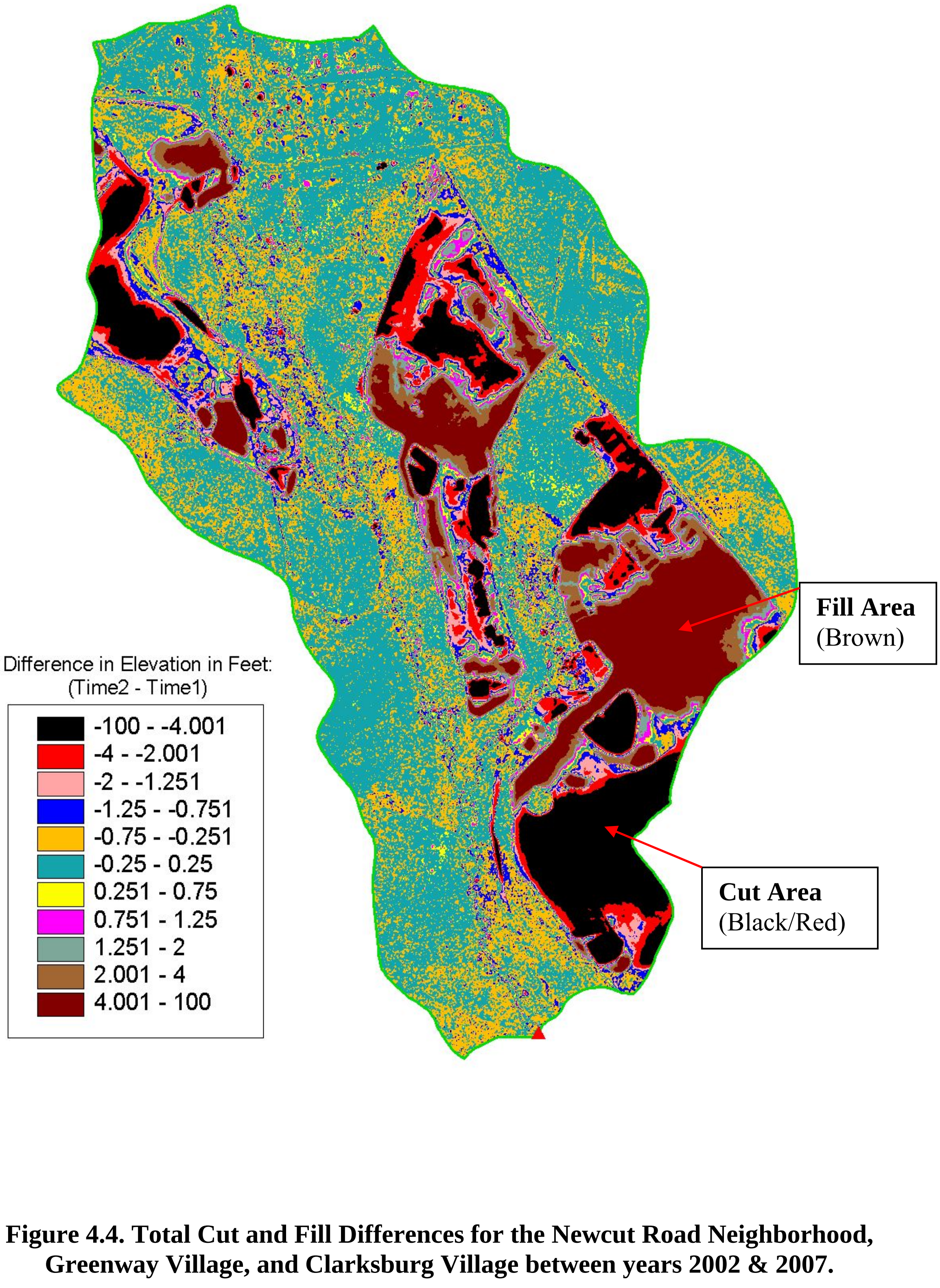

Figure 4.4. Total Cut and Fill Differences for the Newcut Road Neighborhood, Greenway Village, and Clarksburg Village between years 2002 & 2007.

4.2 Hydrology

4.2.1 Background

Conversion of watersheds to urban areas has been shown to have major affects on stream hydrology as a result of vegetation removal, stream channel modification, and increases in impervious area. These alterations can lead to increased *stream flashiness* and hydrologic responses: faster onset and decay of storm flow *hydrographs*, reduction in base flow rates, and higher and earlier peak discharges (Bledsoe 2001; Paul and Meyer 2001; CWP 2003; Goonetilleka et al. 2005; Konrad and Booth 2005; Walsh et al. 2005; Farahmand et al. 2007). The effects of these hydrologic changes are most severe in headwater streams (Nehrke and Roesner 2001). This section builds on the work first reported in the 2007 SPA Annual Report.

The loss of water storage capacity of the hill slopes that have been graded and leveled through urban development (such as shown in the LiDAR series), along with reductions in vegetative cover, topographic depressions, soil depths, and infiltration capacity of the native soils, lead to hydrologic changes (CWP 2003; Konrad and Booth 2005).

4.2.2 Study Design and Data Collection

The study design remains as reported in Section 1.2.2. Maps showing test and control areas, geomorphic survey areas, and stream and precipitation gage locations are provided in the Technical Appendix.

4.2.3 Hydrologic Data Analysis and Interpretation

The rain gages at Black Hill Regional Park and Little Bennett Regional Park have produced records of rainfall totals that allow the calculation of a number of useful statistics including storm durations, storm mean intensity, and storm peak intensity. Rain data used in this report is summarized in Table 4.1.

Stream flow gages continue to provide data that allows the calculation of instantaneous peak discharge and daily mean discharge. The Sopers Branch gage (01643395) and the Little Seneca Creek Tributary near Clarksburg (Newcut Road neighborhood) gage (01644371) data are used in this report (Table 4.2). See Technical Appendix for a map of gage locations. The drainage area to the Newcut Road Tributary gage has had the largest amount of land disturbance relative to the development process than at any of the other four gages. Information on the five gages is presented in Table 4.2.

Table 4.1. Summary of Rain Data Collected From the Little Bennett Rain Gage, Clarksburg Study Area.

Date of Storm	Time (EST)	Storm Duration (Hours)	Storm Rainfall Total (inches)	Average Storm Intensity (in/hr)	Maximum Storm Intensity (in/hr)
June 11, 2004	5:45 - 20:30	14.75	0.81	0.06	0.36
July 23, 2004	16:10 - 17:55	1.45	1.24	0.72	2.64
September 28, 2004	2:00 - 18:25	16.42	2.25	0.12	1.80
June 25, 2006	7:20 - 22:25	22.08	2.64	0.12	3.24
July 5, 2006	21:05 - 23:25	2.3	1.86	0.72	3.48
April 14 to 15, 2007	4/14/17:20 - 5/15/14:15	20.92	2.22	0.12	0.60
June 13, 2007	16:25 - 18:50	2.42	0.68	0.24	1.92
August 25, 2007	15:40 - 21:55	6.25	1.70	0.24	6.00
March 4, 2008	20:00 - 3/5/08 5:05	9.08	0.99	0.01	0.14
March 7, 2008	3/7/08 13:15 -3/8/08 16:00	26.75	0.67	0.002	0.04
April 20, 2008	4/20/08 4:20 - 4/21/08 13:00	32.67	3.08	0.01	0.19
June 27, 2008	6/27/2008 15:50 - 16:15	0.42	0.59	0.10	0.24
June 28, 2008	6/28/2008 19:15 - 20:05	0.83	0.33	0.03	0.08
July 9, 2008	7/9/2008 16:50 - 16:55	0.08	0.32	0.16	0.29
July 13, 2008	7/13/2008 15:45 - 7/14/2008 2:25	22.42	0.68	0.01	0.07
October 25, 2008	10/25/2008 10:15 - 17:00	6.75	1.27	0.02	0.14

Table 4.2. Descriptions of the Five Stream Gages in the Clarksburg Study Area.

Gage Id. Number	Name	Date Started	DA (mi^2)	DA (acres)
01644371	Little Seneca Creek Tributary Near Clarksburg, MD	5/2004	0.43	275.2
01643395	Sopers Branch at Hyattstown, MD	2/2004	1.17	748.8
01644375	Little Seneca Creek Tributary Near Germantown, MD	6/2004	1.35	864
01644372	Little Seneca Creek Tributary at Brink, MD	6/2004	0.37	236.8
01644380	Cabin Branch Near Boyds, MD	6/2004	0.79	505.6

Precipitation, Infiltration, and Annual Flows

Average annual precipitation is about 42 inches in the Baltimore-Washington area (NWS 2008). Average monthly precipitation varies throughout the year and spring and summer thunderstorms can cause significant variations in precipitation depending on location (Doheny et al. 2006; James 1986).

Annual runoff for the two USGS gages (01644371, 016433955) was used to determine how much average annual precipitation infiltrates into the groundwater or is released into the atmosphere through *evapotransporation*. Data were obtained from the online *Water Year Reports* published by the USGS, Baltimore Office (Doheny 2009, personal communication) for water years 2005, 2006, 2007, and 2008 and 2008 Water Year Reports for the Sopers Branch and Newcut Road Neighborhood Stream Gages are provided in the Technical Appendix.

The Sopers Branch had about 62.5% of the average annual precipitation either infiltrating into the ground or lost to evapotransporation during water year 2005, 71.3% in water year 2006, 55.1% in water year 2007, and nearly 70% in water year 2008 (Fig. 4.5). The tributary of Little Seneca Creek had about 66.8% of the average annual precipitation either infiltrating into the ground or lost to evapotransporation during water year 2005, 58.6% in water year 2006, 46.7% in water year 2007, and about 55% in water year 2008. On average, the overall amount of precipitation infiltrating into the ground or lost via evapotransporation steadily declined in the Newcut Road Neighborhood Tributary (Fig. 4.5; blue line) while remaining fairly constant in the Sopers Branch (Fig. 4.5, red line). Figures 4.1 through 4.4 depict the land use changes that occurred within this drainage area during the same time period.

The overall amount of precipitation that directly entered the Newcut Road Neighborhood Tributary to Little Seneca Creek increased over this same time period (Fig. 4.6). Annual flows were adjusted for the differing drainage areas of the two gages to normalize the annual runoff amounts and to allow for comparison.

About twice as much rainfall is running directly into the Newcut Road Neighborhood Tributary stream as compared to the control stream, Sopers Branch for the 2005, 2006, 2007, and 2008 water years (Fig. 4.5). This is due to the changes in imperviousness that have occurred in the drainage area as a result of development.

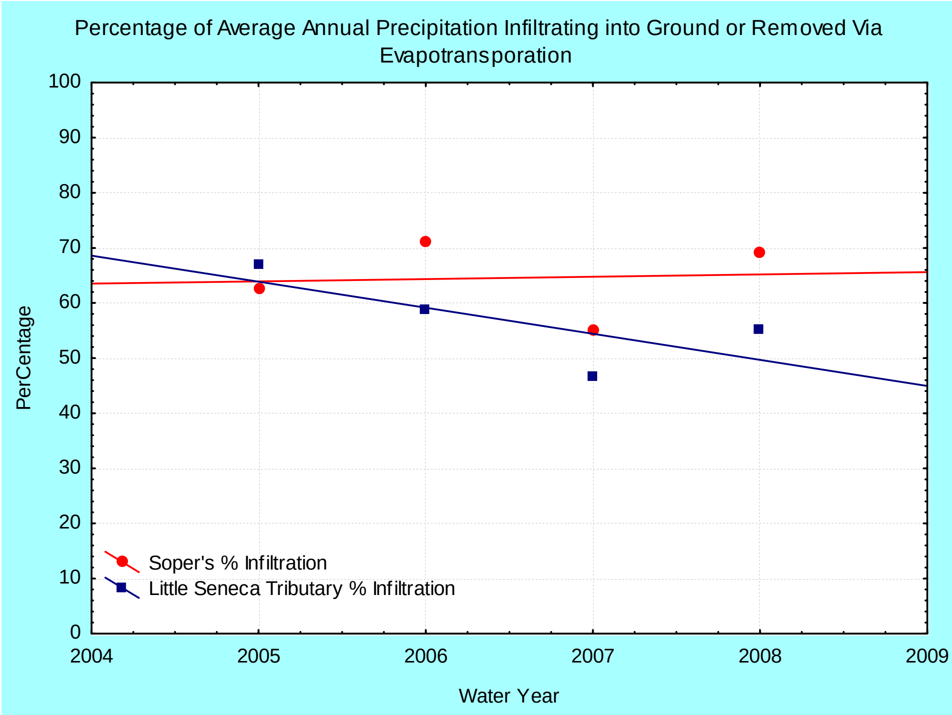

Figure 4.5. Percentage of Average Annual Precipitation Infiltrating into the Ground or Removed via Evapotransporation.

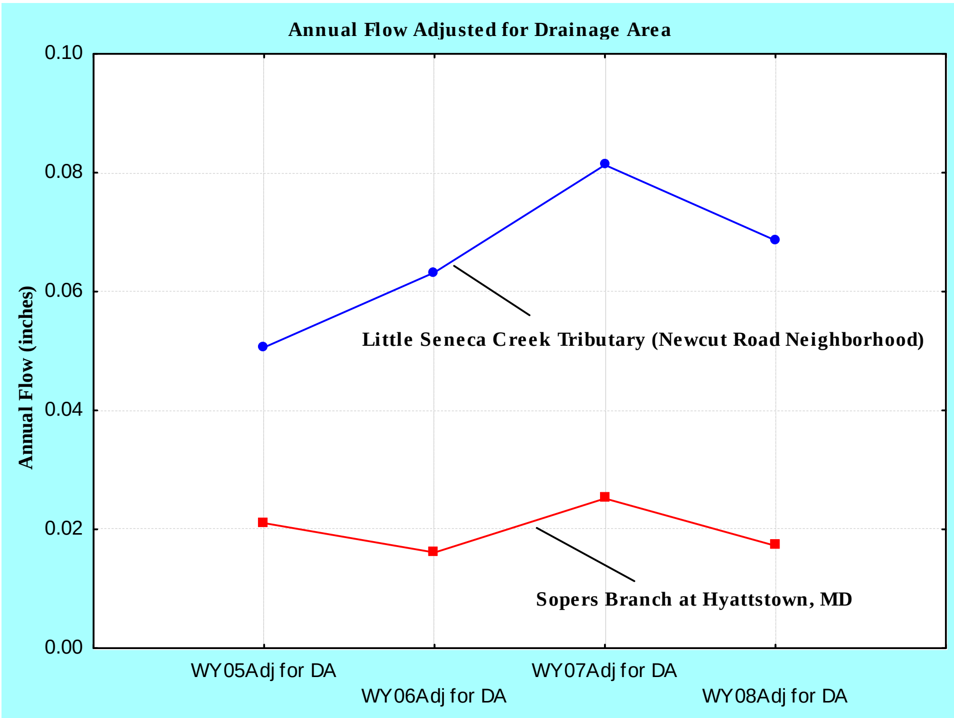

Figure 4.6. Annual Flow (Adjusted for Drainage Area) from 2005 through 2008.

Stream Flashiness

Stream flashiness refers to the stream flow response to storms. Conversion of watersheds to urban areas can lead to flashier hydrologic responses (Farahmand et al. 2007) with water levels that rise, peak, and fall very rapidly in response to storm precipitation (Doheny et al. 2006). An index was used in the 2007 SPA Annual Report to compare the flashiness of the Sopers Branch and Newcut Road Neighborhood Tributary streams (Doheny et. al. 2006). The index is described as the ratio between the instantaneous peak discharge (highest stream flow [IPD]) to the daily mean discharge (average stream flow [DMD]) that occurs during a storm event. When the discharge is divided by the size of the drainage area (acres), the ratios are normalized and the ratios from different streams can be compared.

Figure 4.7 plots the adjusted flashiness index for the two drainages for specific storms that occurred during 2004, 2006, and 2007. During the construction period, the Newcut Road drainage was, on average, flashier than the Sopers Branch drainage (Fig. 4.7). During the later drought period of 2007, the Newcut Road Tributary was noticeably less flashy. In 2008, the Newcut Road Neighborhood Tributary Flashiness Index was higher when storms had higher *average* storm intensities or higher *maximum* storm intensities (Table 4.1). Storms measured in 2008 that resulted in similar Flashiness Indices between the Sopers Branch and Newcut Road Neighborhood Tributary had less then one inch of rain, low average storm intensities, and low maximum storm intensities. A table of daily mean discharge and instantaneous peak discharges for storm events is provided in the Technical Appendix.

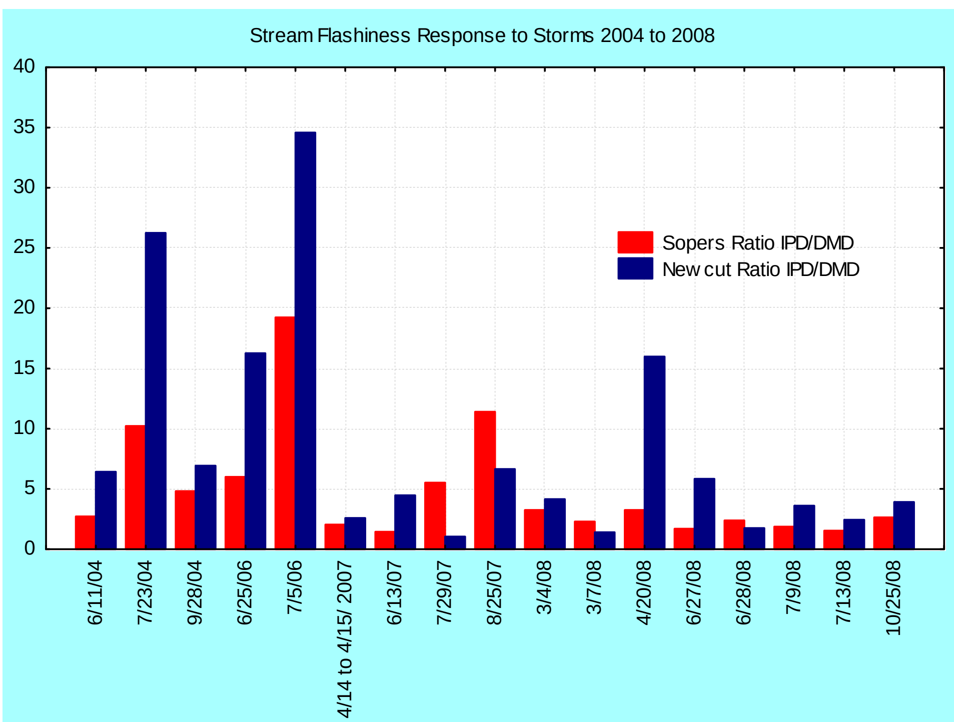

Figure 4.7. Comparison of Stream Response to Storm Events: 2004 to 2008.

Time of Concentration

Time of concentration is defined as the difference in time between the start of rainfall and when discharge begins to increase at the gaging station (Doheny et al. 2006). Changes in the time of concentration of a watershed can be useful in understanding stream response to increases in imperviousness. When the conversion process to SWM BMPs has been completed, time of concentration will be evaluated to determine if the Newcut Road tributary's response to rainfall has changed compared to the control station.

Changes in the storm runoff amounts, directly and immediately reaching the stream, and the flashiness of the stream's response to storms can cause changes in stream geomorphology.

4.3 Changes in Stream Geomorphology

Geomorphology was not surveyed in 2008 due to the staffing needs to complete the 2007 SPA Annual Report. Survey information will be provided in the 2009 SPA report.

4.4 Changes in Physical Chemistry

4.4.1 Water Temperature

Stream water temperature plays an important role in maintaining the health of the stream's biological community. Previous SPA Annual Reports identified the two principal stressors that influence stream temperature as 1) natural variations in air/stream interactions, and 2) thermal impacts due to runoff from impervious surfaces and BMP storage facilities. Water temperature is being monitored at representative BMPs in all SPAs during the pre, during, and post construction phases. The results are presented in Section 3.

4.4.2 Water Chemistry

DEP measures *in situ* (on-site) water chemistry data at biological monitoring stream sites and occasionally in response to incidents (i.e. fish kill). Stream temperature, dissolved oxygen, percent dissolved oxygen saturation, pH, and conductivity are measured using a multi-parameter probe.

These *in situ* data are limited in their use and application because they provide information on the stream only at the time and location of the sample. The data are most useful at measuring the conditions on site as an event is occurring (i.e. sewer line break) and for detecting a chronic condition (such as consistently high conductivity). Continuous sampling provides for the full range of water chemistry changes over time, but the costs and resources needed to provide, maintain, and calibrate a water chemistry recording meter at all SPA stations is prohibitive. Sampling of base flow and storm flow stream chemistry is required at some SPA BMP monitoring projects and is described in Section 3.2.5.

4.5 Habitat

A Rapid Habitat Assessment (RHAB) is used during spring and summer sampling at all stream stations monitored in the county. An individual score is selected within categories of *optimal*, *sub-optimal*, *marginal*, and *poor* and a total score (out of 200) is generated for the station. A summary of the RHAB methods used by DEP is provided in the Technical Appendix (Section TA-5.2).

There is no clear trend in the three SPAs and no substantial difference was found between the test and control areas.

4.6 Summary

4.6.1 Landscape Changes and LiDAR

Overall, the topography, natural drainage patterns, and naturally diffuse infiltration have been altered due to the cut and fill levels necessary to meet the requirements of the Newcut Road Neighborhood developments. Most of the stormwater runoff is now diverted into stormwater inlets and drains rather then infiltrating into a pervious surface over a wide area.

4.6.2 Hydrology

The greater the impervious surfaces that cover a watershed, the smaller the amount of precipitation that infiltrates into the groundwater system and the more precipitation directly runs off into streams. This is through the grading and compaction activities that currently occur as a result of development. Naturally pervious soils and a diffuse infiltration system are altered and/or lost through the cut and fill requirements currently being followed to develop a property.

The natural hydrology of the Newcut Road Neighborhood in Clarksburg has been altered dramatically by the development process. The ability of BMPs to mimic pre-construction hydrologic conditions will be evaluated once the construction process has been completed and the SWM BMPs are online and functioning as designed.

On average, the overall amount of precipitation infiltrating into the ground or lost via evapotransporation has steadily declined in the Newcut Road Neighborhood Tributary while remaining fairly constant in the Sopers Branch control. The overall amount of precipitation that directly entered the Newcut Road Neighborhood Tributary test area also increased over this same time period as compared to the Sopers Branch.

SWM BMPs in SPAs are designed to promote infiltration and recharge. Not all structures are online and fully-functional in the Newcut Road Neighborhood.

4.6.3 Physical Chemistry

Stream water temperatures rise and fall according to a diurnal pattern that follows air temperatures although there is generally a lag in stream water temperature response. For example, maximum water temperatures are generally reached after 6:00 pm. Springs and seeps provide cold groundwater recharge into streams. Forested stream buffers help to keep the stream water cold, much like an insulating thermos keeps liquids at temperature. Impervious surfaces will increase water temperatures in streams as stormwater runoff passes over the thermally heated materials. Similarly, forested stream buffers also act as filters, reducing pollutants in stormwater before it enters the stream. Impervious surfaces can reduce buffering capacity by increasing the amount of runoff and introducing more opportunities and pollutants to enter stream.

Some SWM BMPs in SPAs are designed to cool heated stormwater runoff through prolonged underground contact that promotes heat exchange in an aim to prevent further impacts. Other SWM BMPs function to treat stormwater quality through pollutant removal. Using a variety of SWM BMPs within a treatment train can help prevent impacts to water quality and aquatic life.

No noticeable difference in physical chemistry was observed between the Clarksburg control and test stations over time.

4.6.4 Habitat

The data that have been collected through the Rapid Habitat Assessment do not show major differences in habitats of streams that lie within watersheds with land development projects versus those that are in watersheds with very little or no land development activities. The assessment may be too coarse to detect differences; the geomorphic surveys provide a quantitative method to measure differences between control and test areas.

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5. Biological Stream Monitoring

Stream biological communities respond to the cumulative and multiple stressors that occur in the stream. Careful monitoring and comparison of streams not impacted by new development and streams with ongoing development can isolate stressors caused by natural conditions (drought, flooding) from those caused by development (mass grading, sedimentation, increased impervious surface). Development-related landscape changes can alter stream hydrology and channel shape. SPA S&E and SWM BMPs attempt to minimize these impacts.

5.1 Background

Minimization of the cumulative effects caused by development and land use change to streams is made through careful land use planning, protection of sensitive environmental features, and development practices that maintain natural hydrological and channel processes.

Biological monitoring evaluates stream condition and records changes in the stream community over time. The U.S. EPA (1990) recommends using two or more indicator groups to provide a more realistic evaluation of system *biological integrity*. The monitoring of fish and benthic macroinvertebrate communities is used nationally and regionally to measure the overall health of a stream, as documented in the 2007 report. Both biological communities provide information on short-term and long-term impacts.

Fish and benthic macroinvertebrate populations display a range of tolerances within each community and these populations will survive or die in relation to the degree of cumulative impacts in the stream. Adults may survive intitially, but the cumulative impacts can affect reproductive success to the point where there are not enough viable offspring produced to maintain the population. For examples of *tolerance values* and *functional feeding groups*, see the Technical Appendix. DEP developed an index to compare the stream community (fish and benthic macroinvertebrates) to those found in the least impaired streams located in the County and surrounding areas.

Measures (*metrics*) of each biological community are assembled to form an *Index of Biological Integrity (IBI)*. The metrics used for benthic macroinvertebrate and fish IBIs can be found in the Technical Appendix. Metrics are selected that respond in a predictable way to increasing degrees of cumulative impacts. Metrics are scored in comparison to the least impacted streams in the region. The final IBI creates an index that compares any stream against conditions found in these least impacted streams. Streams are rated as *excellent*, *good*, *fair*, or *poor*.

Benthic macroinvertebrates tend to be stronger indicators of stream health in headwater areas with short term disturbance, where impacts to the stream are much more concentrated in time and space. Fish, with longer life-spans and increased mobility, give stream health information on a larger scale both spatially and temporally. Combined in an average, the benthic and fish metrics give a very inclusive, holistic evaluation of a stream's overall biological condtion.

DEP has been performing county-wide biological monitoring since 1994. DEP began stream monitoring within three SPAs, Clarksburg, Piney Branch, and Upper Paint Branch in 1995 and within the newly-designated Upper Rock Creek SPA in 2004. Stream monitoring includes biological sampling of benthic macroinvertebrate and fish, as well as amphibian and reptile populations. Stream monitoring also includes habitat assessment, stream channel measurements, and water quality readings (dissolved oxygen, temperature, pH, and conductivity), which were discussed in Section 4. For a table of available stream monitoring data and a discussion of stream monitoring protocols, see the Technical Appendix.

A Stream Salamander IBI has been developed for Maryland and has undergone several validations (Southerland et al. 2004; Southerland and Franks 2008). Stream salamanders spend their entire lives instream or closely associated with the stream channel. Because of their longevity, small *home ranges*, relatively stable populations, abundance and ubiquity, salamanders have been identified as promising indicators of water quality. Furthermore, they replace fish as top predators in small, headwater streams (Jung et al. 2004; Southerland and Stranko 2006). DEP is examining the use of stream salamanders as indicators of water quality in small streams (less than 300 acres drainage area) to complement the benthic macroinvertebrate IBI scoring results.

Presently, there are 57 SPA stream monitoring stations throughout the four SPAs: 27 in Clarksburg; 14 in Upper Paint Branch; 10 in Piney Branch and six in the Upper Rock Creek SPA. Because of staff constraints, not all 57 stations are able to be monitored each year. 49 stations were monitored in 2008. For maps showing the location of all active SPA biological monitoring stations in the four SPAs, see the Technical Appendix.

5.2 Stream Condition Comparison

This section compares the stream conditions (the average of the fish and benthic IBI scores) at each station of the four SPAs from the start of SPA stream monitoring (1994) through 2008. Changes to the stream conditions in the four SPAs are presented and discussed. These changes are from cumulative impacts – not always from impacts directly related to SPA development. Changes to SPA stream conditions are presented along with possible stressors related to the change. Section 5.3 presents changes in stream conditions associated with SPA development impacts.

According to Morgan and Cushman (2005), small (1st to 3rd order) headwater streams are particularly at risk from development impacts. Altered flow regimes from urbanization can affect fish assemblage structure and biodiversity by re-shaping the streams physical habitat on too short a time scale (years to decades) to allow populations to adjust. Miltner et al. (2003) suggested that poorly regulated construction practices constitute the first step toward declining stream health in suburbanizing landscapes.

5.2.1 Clarksburg SPA

Clarksburg SPA stream conditions were predominantly *good* to *excellent* before development occurred (Fig. 5.1). Currently, stream conditions in the Clarksburg Town Center (above Stringtown Road), an eastern tributary of Ten Mile Creek (mostly east of I-270), and a developing area of the Newcut Road development have dropped into the *fair* category (Fig. 5.2). The most upstream site on the Town Center Tributary (LSLS103C, located just downstream of Stringtown Road) that is closest in proximity to the Town Center development also declined from its pre-development conditions and is ranked *fair*.

The farthest downstream Town Center Tributary site, located below Foreman Boulevard (LSLS103B) and near the confluence with Little Seneca Creek, improved from *fair* in 2007 to *good* in 2008. This area drains portions of the Newcut Road and Town Center developments, Highlands of Clarksburg development, and some older pre-SPA large-lot neighborhoods. The Highlands of Clarksburg development has completed construction and is generally stable, although monitoring of post-construction conditions has not yet commenced. Generally, the Newcut Road Neighborhood developments have been progressing in phases from east to west, with the biological impairment following a similar pattern.

Stream conditions at GSWB201 also improved from *fair* to *good* from 2007 to 2008. The SWM structures received as-built approval in June 2007, following site stabilization and completion of development. Development of this formerly agricultural site consisted of construction of a cemetery, mausoleum, small chapel and maintenance facilities. The majority of the cemetery is open space. BMP monitoring indicated that changes to the stream channel occurred during construction activities but that the channel was relatively stable from 2007 to 2008 (Section 3.2.7).

Brown trout—indicators of good water quality—were again found in Ten Mile Creek. It is not known whether these trout are naturally occurring, but no signs of fish stocking, such as fin erosion, were observed.

“There are few watersheds that can compare to the Ten Mile Creek watershed’s rich and diverse ecosystem within Montgomery County” (M-NCPPC 2009).

The eastern headwater area of Ten Mile Creek remains in *fair* condition. Current imperviousness is 12%. This area partially receives runoff from some of the Clarksburg Detention Center, the new Stringtown Road widening west of Route 355, some commercial development in the I-270 Gateway Center area, portions of the Town Center development, a part of Gateway Commons, as well as runoff from portions of I-270. An investigation was made into possible reasons for the decline (as reported in the 2006 SPA Annual Report) and high conductivity readings were found throughout the drainage area to the station. No specific cause for the high conductivity readings could be identified, but the sensitivity of Ten Mile Creek to impacts is apparent.

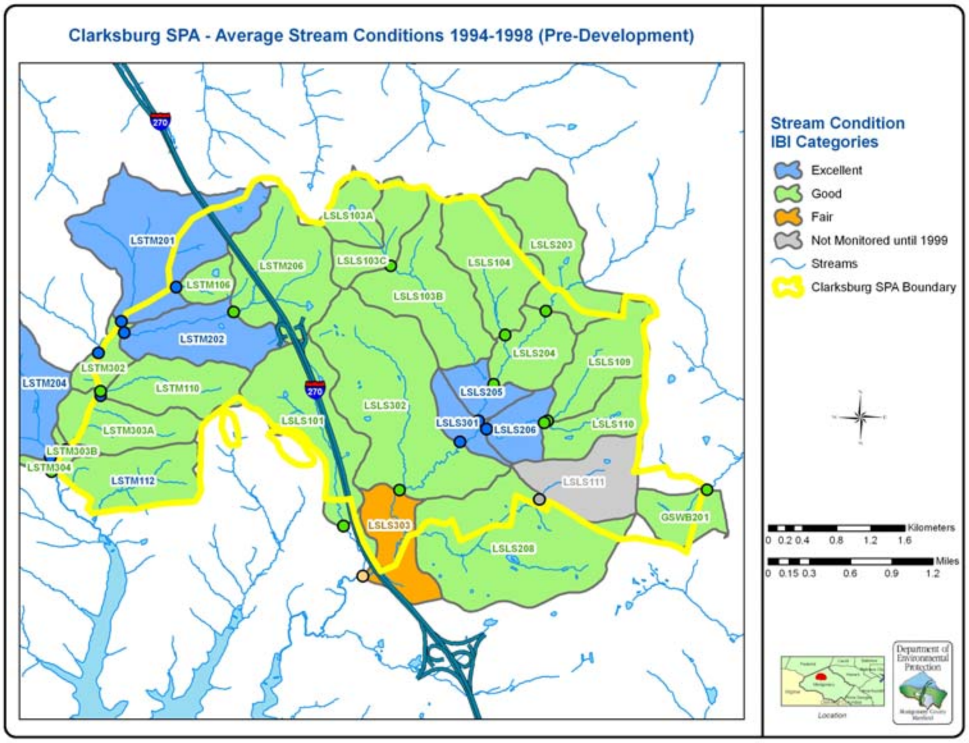

Figure 5.1. Pre-development (1994-1998) Stream Conditions (average of fish and benthic % IBI scores) in the Clarksburg SPA.

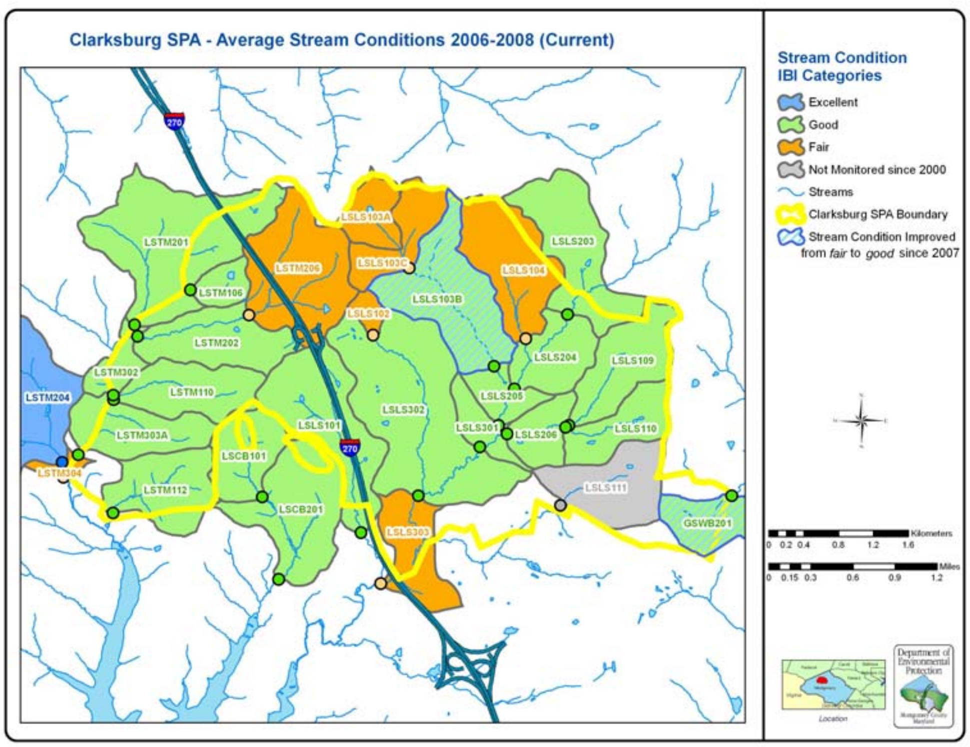

Figure 5.2. Current (2006 - 2008) Stream Conditions (average of fish and benthic % IBI scores) in the Clarksburg SPA.

5.2.2 Paint Branch SPA

Paint Branch stream conditions were also predominantly *good* to *excellent* before the development period (Fig. 5.3). Current stream conditions in the Right Fork tributaries have dropped only slightly from *excellent* to *good* (Fig. 5.4). Most of the SPA development within Paint Branch has occurred in the Right Fork of the Upper Paint Branch.

One station in the upper Left Fork (PBLF202) went from *fair* in 2007 to *good* in 2008 (Fig. 5.4). The drainage area to PBLF202 is approximately 466 acres. Snider's Estates, an 8 acre residential subdivision, is the only new SPA development in this area. SWM at Snider's Estates has been functional and online since December 2004. It is unclear whether a correlation exists between SPA development activities and the stream condition in this watershed since the surrounding existing development confounds the interpretation. However, it appears the small scale of development and the quick conversion likely helped mitigate any new impacts to stream conditions.

Presently, only one station in the headwaters of the Good Hope Tributary, PBGH108, is in *fair* condition, with all other areas sustaining a *good* condition. The only SPA development activities occurred at the Cloverly Safeway. Less than five acres of the Safeway property drains to the Upper Paint Branch SPA; the remainder of the small property drains away from the SPA. Construction activities were associated with the redevelopment of an existing commercial site, and SWM has been online and functional since 2002. The headwaters of the Good Hope (in the vicinity of Peachwood Park) have been in *fair* condition since the County monitoring began in 1994 (Fig. 5.3).

The Good Hope relies on clean, cool waters as spawning grounds for its naturally-reproducing brown trout population. Discussion of Paint Branch Brown Trout is located in the Technical Appendix. In 2008, brown trout, one of the most sensitive fish species in Montgomery County to stream degradation and water quality impairment, were still present in the Upper Paint Branch SPA. Both the Upper Rock Creek SPA and Paint Branch SPA have an 8% impervious surface cap.

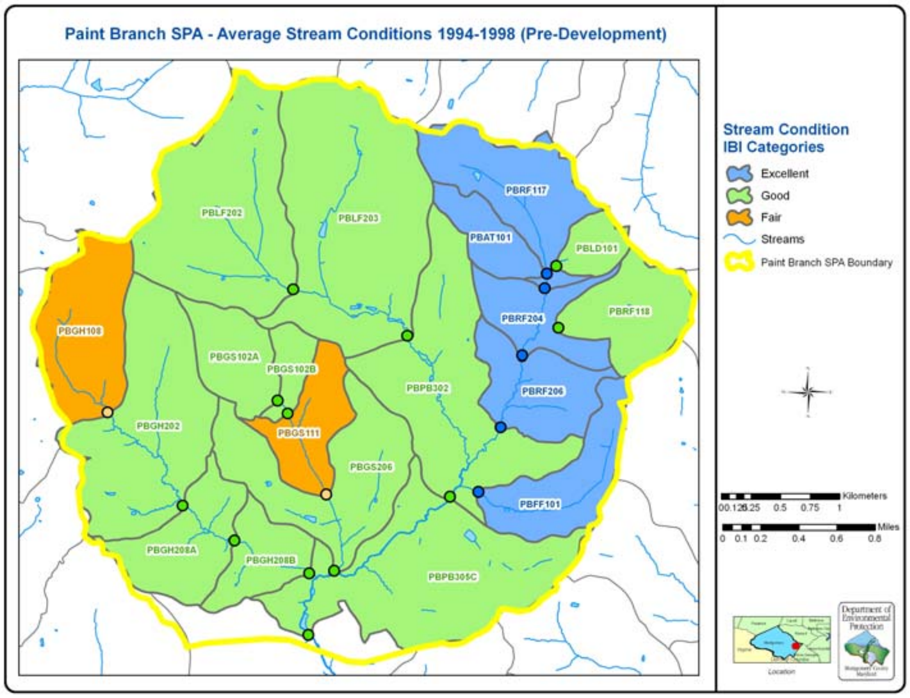

Figure 5.3. Pre-development (1994-1998) Stream Conditions (average of fish and benthic % IBI scores) in the Paint Branch SPA.

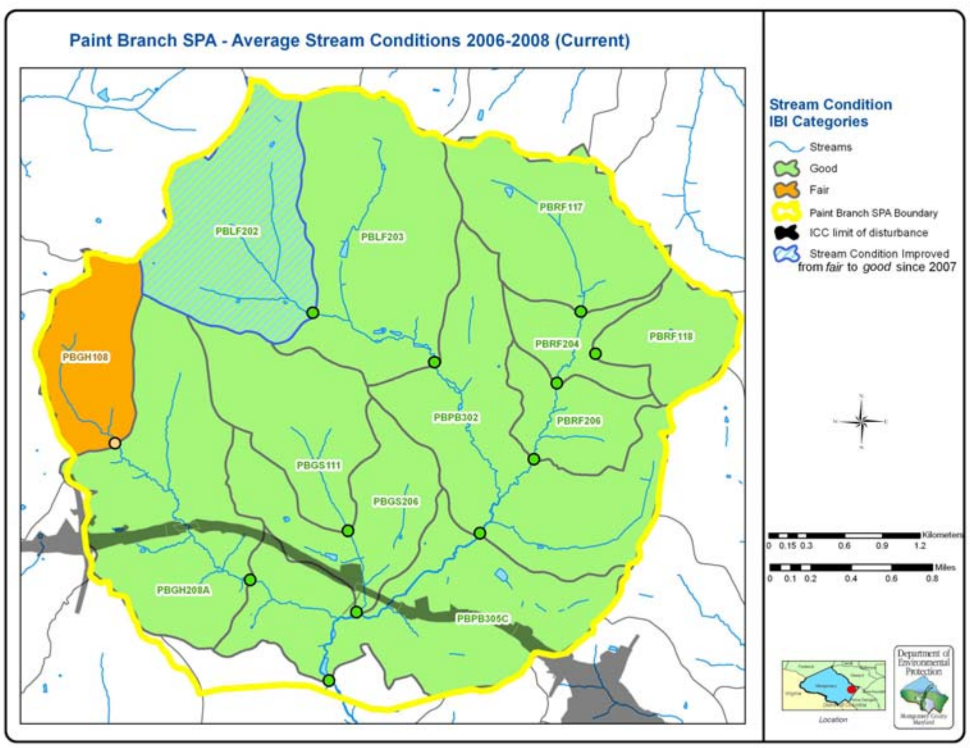

Figure 5.4. Current (2006 - 2008) Stream Conditions in the Paint Branch SPA.

5.2.3 Piney Branch SPA

The stream conditions in the upper headwaters area of the Piney Branch SPA went from predominantly *fair* before development (Fig. 5.5) to *fair* and *poor* (Fig. 5.6). New development occurred during this time. In 2008, two stations in the upper headwater area of Piney Branch improved to *fair* from their condition in 2007 of *poor*. These stations (WBPB201 and WBPB202) are in close proximity to each other. The stream condition at the station downstream of these, WBPB203A, remains unchanged.WBPB202, the station upstream of WBPB203A, is in a portion of the Piney Branch within the older Piney Glen Village and Willows of Potomac developments. These developments started before the SPA program began. The upper station (WBPB201) is also partially within these older developments. In addition, it receives flow from the Gudelsky SWM pond and areas of the Traville development. WBPB102, which drains a major portion of Traville, remains *poor,* as reported in 2007.

Traville (approximately 140 acres of land) represents a consortium of projects. While construction on some properties has been completed and S&EC converted to SWM since 2000, other portions just began stabilization and conversion in 2007 and 2008. Furthermore, the majority of the individual properties are linked by a large SWM facility which was undergoing inspection and as-built certification during 2008 and may not have been functioning as designed. As-built approval and issuance of a post construction stream monitoring bond occurred in April 2009. Monitoring of pollutant removal efficiency of this SWM BMP is anticipated. Stream conditions will be monitored as new SPA developments are completed and SWM controls are functioning as designed.

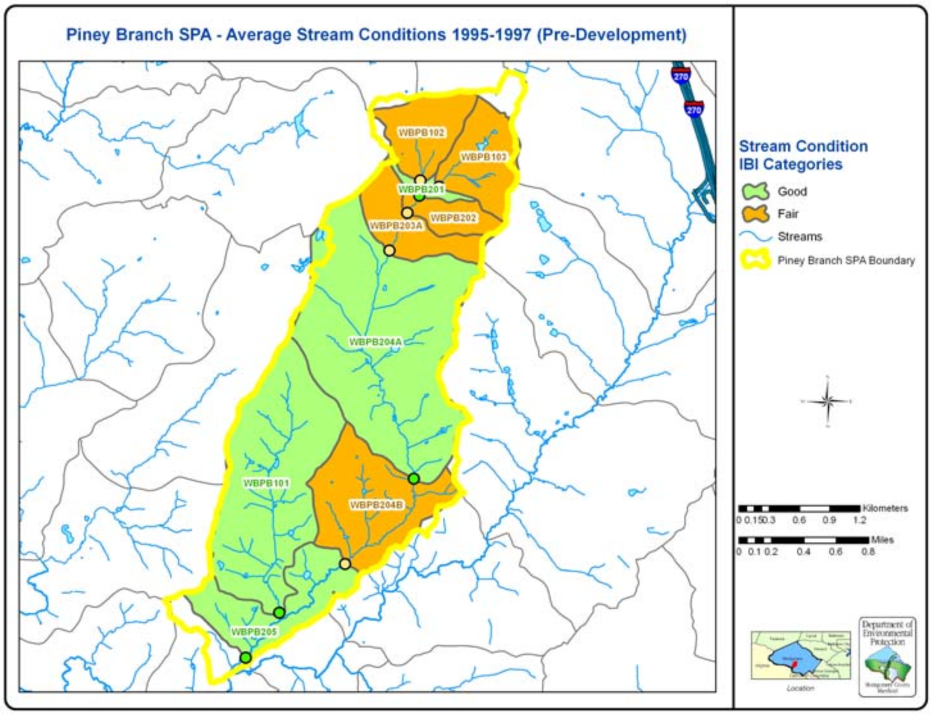

Figure 5.5. **Pre-development (1995-1997) Stream Conditions (average of fish and benthic % IBI scores) in the Piney Branch SPA.**

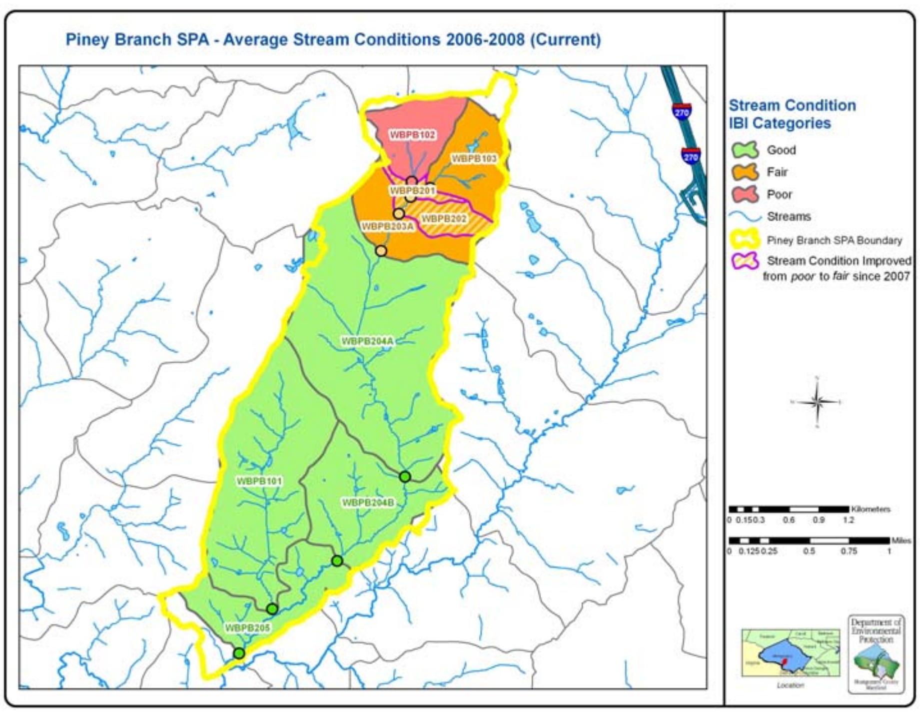

Figure 5.6. **Current (2006 - 2008) Stream Conditions in the Piney Branch SPA.**

5.2.4 Upper Rock Creek SPA

Annual monitoring of SPA stations began in 2004 in Upper Rock Creek. Some data pre-dating 2004 are available from County baseline stations that were established and monitored before part of the watershed was designated as an SPA. Not all baseline stations with historical data were monitored in 2008.

Phase I of the Reserve at Fair Hill began in May 2007. This project occurs above the intersection of Wickham Road and Tackbrooke Drive in Olney (Fig. 5.7). Station URNB111 (about 200 feet above this intersection in a small headwater stream) has maintained a *good* condition (Figs. 5.8 & 5.9). Only 40% of the current development for the Reserve at Fair Hill is within the drainage area for URNB111. Much of the suitable benthic habitat was buried by approximately one foot of fine sediment in 2008.

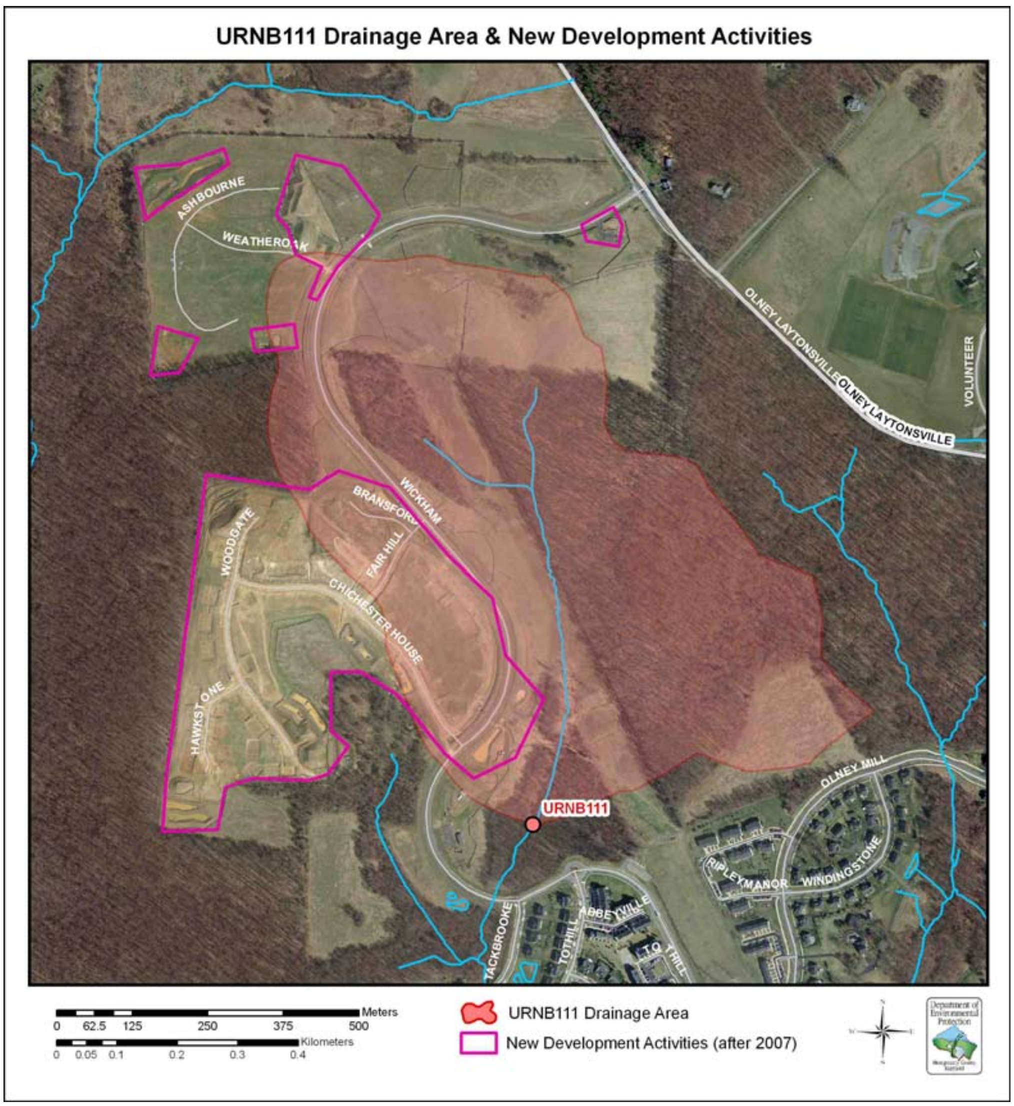

Figure 5.7. Potential (post-2007) Development impacts from Reserve at Fair Hill Project to Biological Monitoring Site URNB111 in Upper Rock Creek SPA.

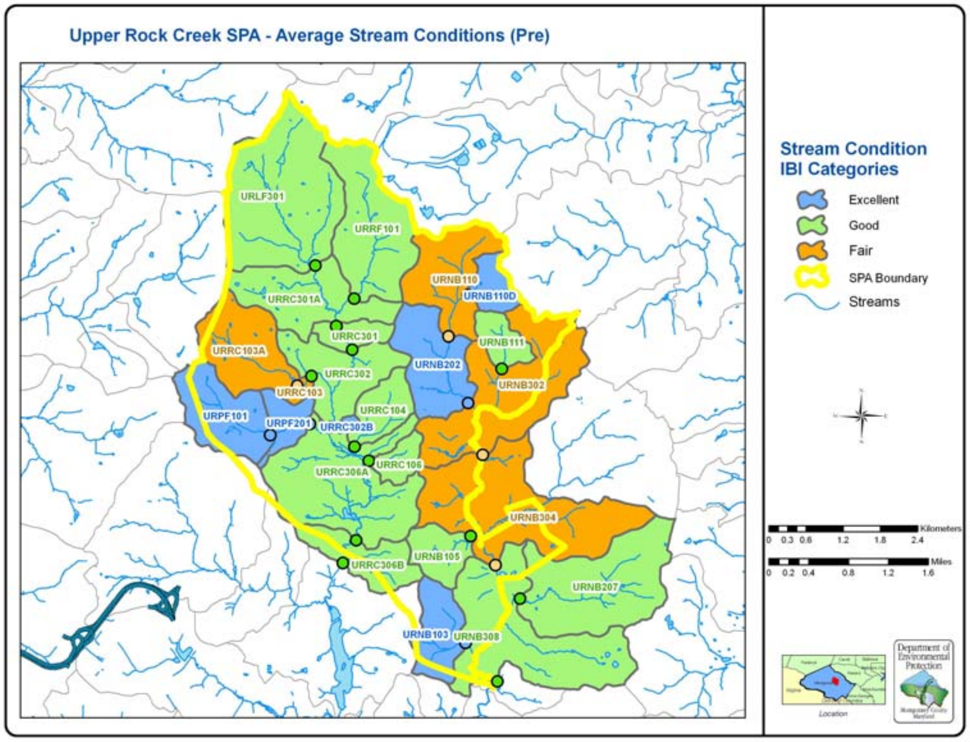

Figure 5.8. Pre-development (2004-2007 for SPA Stations, and pre-2003 for Baseline stations) Stream Conditions (average of fish and benthic % IBI scores) in the Upper Rock Creek SPA.

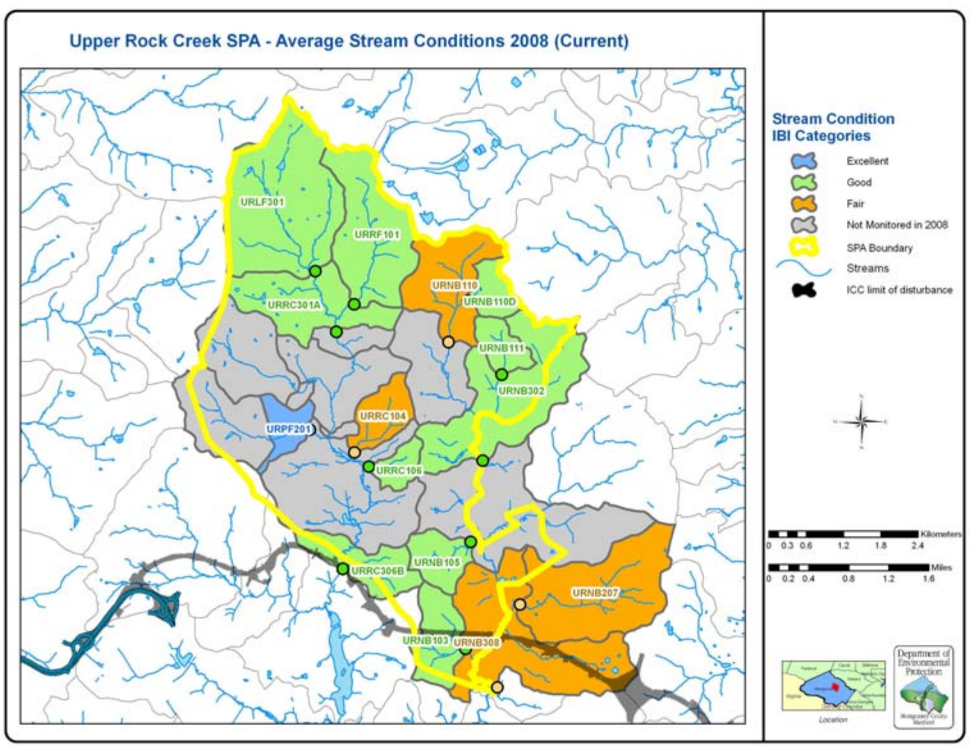

Figure 5.9. Current (2008) Stream Conditions in the Upper Rock Creek SPA.

URRC104, below and to the east of the intersection of Muncaster Road and Willow Oak Drive, has had no SPA development, but has had a *fair* stream condition for the past few years (Fig. 5.9). The site has received lower habitat scores due to silt deposits. One area (URNB302) of the Upper Rock Creek SPA improved from a *fair* condition in 2003 to a *good* condition in 2008 (Fig. 5.9). The area is below the Bowie Mill Estates and Bowie Mill Road and has residential development that was completed in the 1990s.

In November 2007, contract A for the ICC began construction (which extends through the lower portion of the Upper Rock Creek SPA). In addition to the stream monitoring conducted by DEP, the State Highway Administration (SHA) is funding monitoring to determine potential impacts to the streams.

5.3 Benthic Macroinvertebrate IBI Score Comparison

In order to evaluate how effective the SPA methods, facilities, and practices utilized through the construction phase of development are in protecting the water quality of streams in the SPAs, changes in benthic macroinvertebrate IBI ratings of a control set of monitoring stations and a test set of monitoring stations were compared over time before and during the development period for the Upper Paint Branch SPA, Clarksburg Master Plan SPA, and the Piney Branch SPA (Table 5.1).

The control set of stations had no SPA development (i.e. no new areas of disturbed land) occur in station drainage areas; the test set of stations had the majority (greater than 50%) of their drainage areas disturbed through the SPA development process.

Monitoring was done at the same time of year using the same methods. Each SPA was analyzed separately because different levels of development land use controls were in place for each SPA. Stations within each SPA are in close proximity so that the same naturally occurring events within each SPA would affect all stations. Benthic samples were collected in the spring of the year, so summer/fall drought impacts would be reflected in the results of the following year.

The rationale for concentrating on benthic macroinvertebrate scores is that most of the stations used for this comparison are small headwater streams, where benthic macroinvertebrates are expected to be a more responsive indicator group. Fish species that live in the smaller headwater streams tend to be able to survive in the available habitat and are called *pioneer species*. Pioneer fish species are generally more tolerant to disturbance and are able to survive a wider range of stressors than the benthic macroinvertebrate community and respond differently overall.

Table 5.1. Control and Test Stations.

SPA	Control Station Watersheds	Control Stations	Test Station Watersheds	Test Stations
Clarksburg	Ten Mile Creek, Little Seneca Creek	8	Little Seneca Creek (primarily Newcut Road & Town Center Neighborhoods)	9
Piney Branch	Western Tributary of Piney Branch	1	Stations above Glen Hill Road	5
Upper Paint Branch	Good Hope, Gum Springs	4	Right Fork	6
Upper Rock Creek	Portions of Upper Rock Creek North Branch and mainstem of Upper Rock Creek	5	N/A *(no watershed has ≥50% new SPA development as of 2008)*	0

5.3.1 Clarksburg

Land use in the control area is predominately rural agricultural and topography has not changed. Many of the control stations are from Ten Mile Creek. The test set of stations had the majority of its drainage areas disturbed through the SPA development process. Most of the test stations are in the Town Center and Newcut Road Neighborhoods.

Clarksburg median benthic index scores for both the control and test stations were very similar from 1995 to 2002 (Fig. 5.10). Median scores were in the *good* to *excellent* range during this period. Construction began in the Clarksburg test areas in 2002; a record drought also occurred during 2002. The median scores diverged in 2003. The stations under construction dropped to a *fair* condition, while the stations without the development dropped but remained in the *good* benthic IBI category. From 2003 onwards, the streams within the test areas dropped to a *fair* condition and remain *fair* in 2008.

The Town Center tributary's farthest downstream test station (LSLS103B) improved from a *fair* to a *good* condition, perhaps from the lull in active construction activities, completion of construction and stabilization of the Highlands of Clarksburg development, and dilution effects from being far enough downstream from the Town Center. The upstream Town Center test station (LSLS103C) remains in a *fair* condition. Streams in the control areas improved and recovered after the 2002 drought.

The lines, or "whiskers" on the graph, which extend above and below the median points, indicate the range of scores for each group of stations during each monitoring year (25^{th} and 75^{th} percentiles). As the median score of the test and control stations diverge, the range of scores recorded for the two groups also diverge until they no longer overlap in 2005. The scores of the undeveloped control and developed test stations were significantly different from 2005 to 2007. In 2008 they slightly overlap again.

During the 2008 sampling period, one of the control stations was dry and was not sampled. The station was also dry in 2009. This station is on the King Spring. Upon further investigation in 2009, staff found that a beaver dam had been built upstream of the station and had diverted the King Spring flow into a new channel. If the King Spring continues to flow in the new channel in 2010, the station will be relocated to the new channel. Enough time should have passed to allow for colonization of the new channel by benthic macroinvertebrates.

Based on the available data, the development process during this time had a measurable impact on stream conditions in the Little Seneca Creek watershed. There is a slight recovery seen for the test group as a whole in 2008.

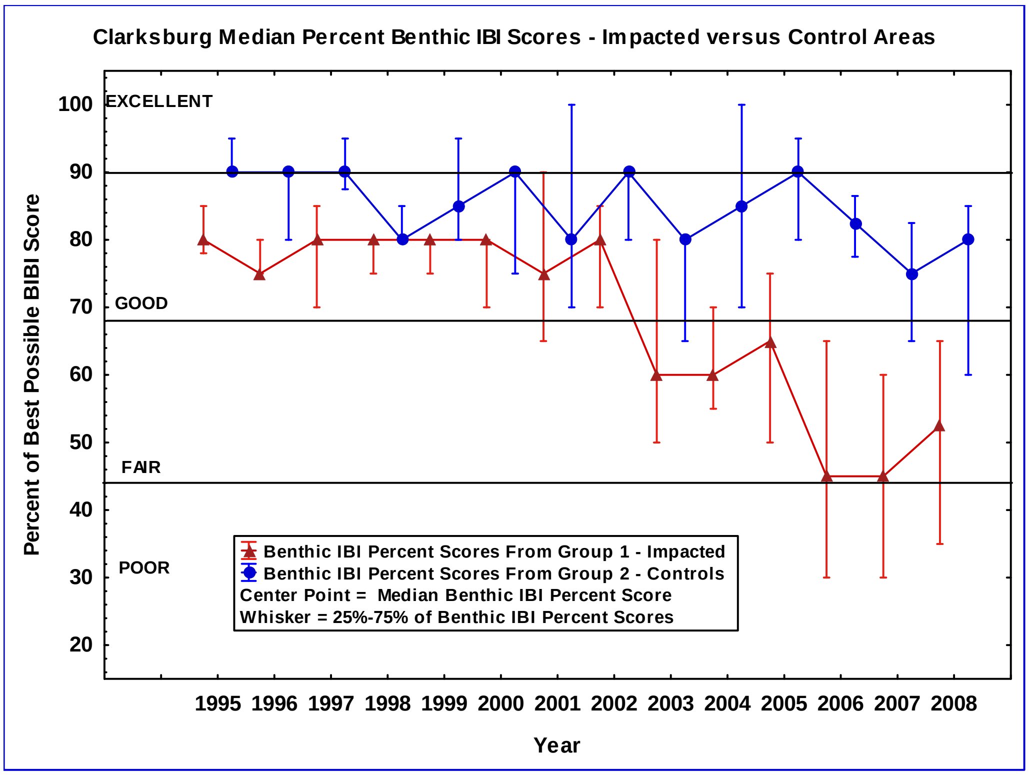

Figure 5.10. Median Benthic IBI Scores for Clarksburg Control and Test Areas.

5.3.2 Piney Branch SPA

Results are very similar to the Clarksburg SPA for the control and test stations in the Piney Branch SPA (Fig. 5.11). Changes in median stream conditions among test and control stations followed each other closely until 1998. Much of the new SPA development in the upper Piney Branch has occurred since 1998. From 1998, benthic IBI scores in the control station stayed in the *good* range. Benthic conditions in the test stations declined to *poor* in 1999 and stayed in the *poor* range since 2003. Again, naturally occurring events such as drought and rainfall affected all stations at the same time. The test stations had the majority of their drainage areas in the development process during this time. Due to the extensive development prior to the establishment of Piney Branch SPA (Section 3.1), only one control station is available for analysis.

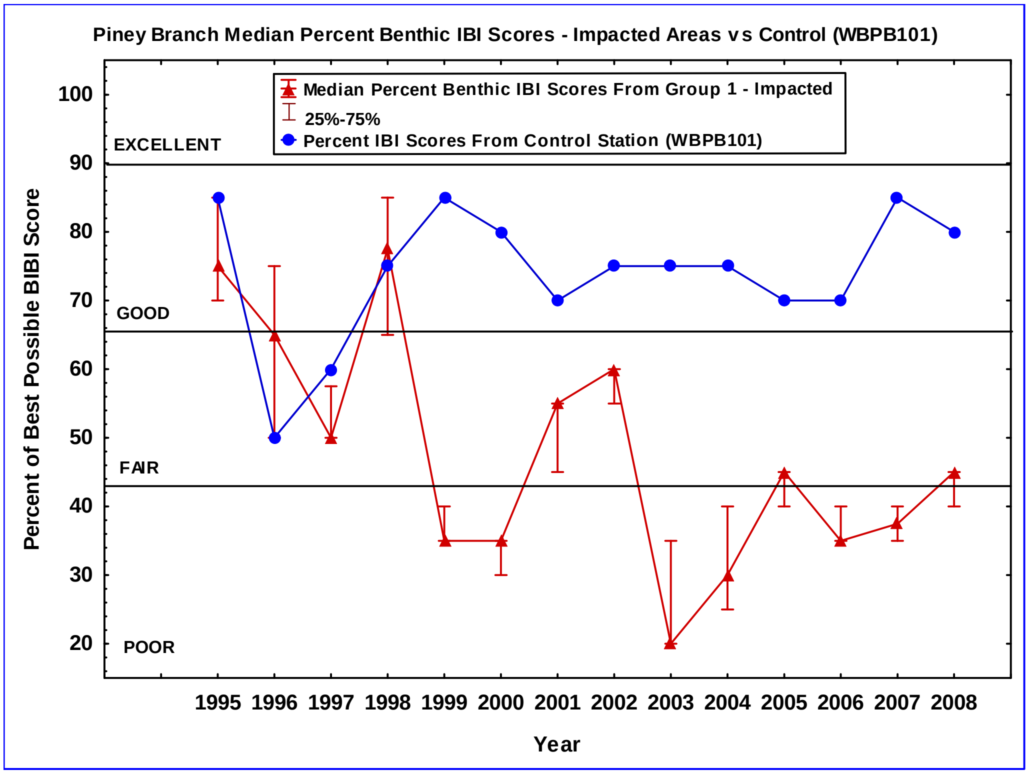

Figure 5.11. Median Benthic Macroinvertebrate IBI Scores for Piney Branch Control and Test Areas.

<u>5.3.3 Upper Paint Branch SPA</u>

The time series between control and test stations for the Upper Paint Branch SPA stations are quite different from the Clarksburg and Piney Branch SPAs (Fig. 5.12). Annual changes in both the test and control stations show similar benthic community ratings. There is no significant difference between the test and control stations that can be attributed to the development processes occurring in the test stations drainage areas, as the percentiles of both the test and control stations fully overlap.

The 2002 drought had a major impact to the Upper Paint Branch as shown in the benthic scores beginning in 2003. The Right Fork of the Upper Paint Branch is likely to recover to near pre-construction level stream conditions. Although measurable impacts are present in the test stations, the benthic community structure remains intact and basically unchanged after the majority of the development in the Right Fork subwatershed has been completed and BMPs converted from S&EC to SWM facilities. This recovery will be monitored after the new SWM controls are functioning as designed.

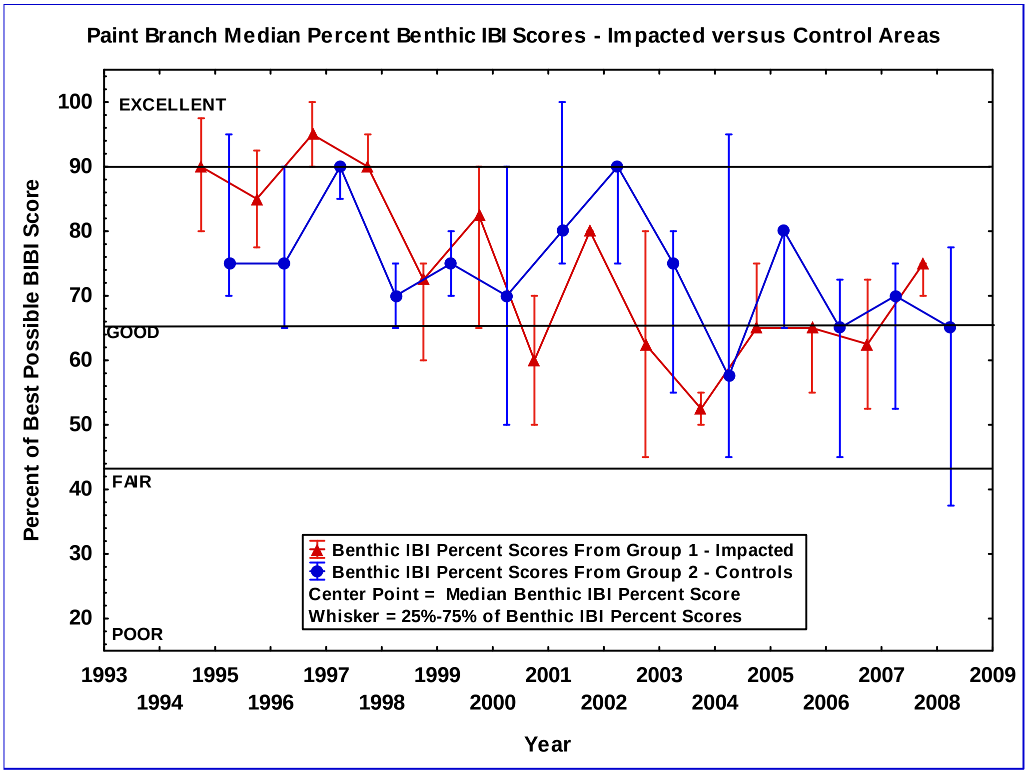

Figure 5.12. Median Benthic IBI Scores for Upper Paint Branch Control and Test Areas.

According to monitoring data going back to 1994, brown trout populations have persisted in the Upper Paint Branch SPA. See the Technical Appendix for more information.

<u>5.3.4 Upper Rock Creek SPA</u>

Benthic IBI scores in the small headwater streams monitored for the Upper Rock Creek SPA have consistently been *good* since 2004 (Fig. 5.13). Stations are not separated into control and test areas at this time. However, there will be test sites in 2009 to incorporate in the next report. One drainage area (URNB111) has had new construction activities occur since the last report, but not over the majority (≥50%) of its drainage area. In May 2007, mass grading and the construction of S&EC facilities have occurred for Phase I of the Reserve at Fair Hill development. The benthic community at URNB111 has retained a score of *good.* However, the benthic habitat was noted in 2008 to be predominantly buried in fine sediment, so there may be a response in the benthic community in years to come.

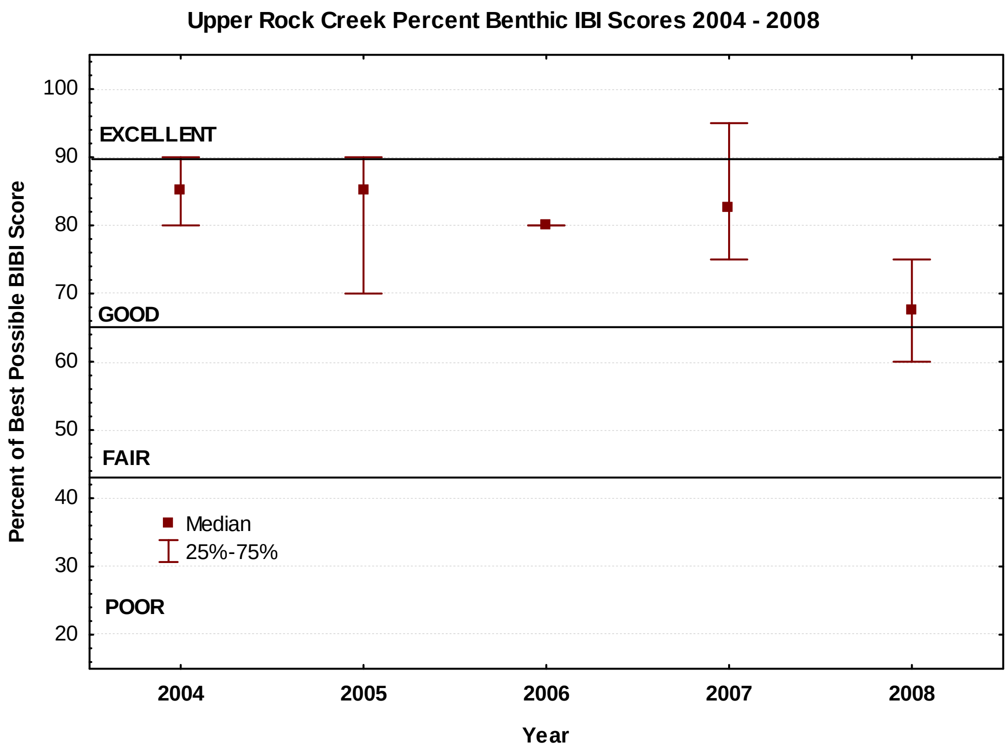

Figure 5.13. Median Benthic IBI Scores for Upper Rock Creek Control and Test Areas.

5.4 Changes in Benthic Macroinvertebrate Community Structure and Function

5.4.1 Introduction

Previous SPA reports discussed the expectation that the stream conditions in the watershed will recover to pre-development levels once the development process in the watershed is completed. Predicting the recovery potential requires understanding the shifts within the biological community. Examinations of individual metrics were used to determine the cause of the changes to the biological community rating. See the Technical Appendix for a complete list of metrics that comprise both the fish and benthic IBIs.

This section of the report examines changes over time using metrics of community structure (dominant *taxa*) and community function (functional feeding groups) for the benthic macroinvertebrate community. Dominant taxa are those organisms that make up the majority of the sampled community. Functional feeding groups are designations that characterize how organisms in the community obtain food and function in the ecosystem. For more discussion on functional feeding groups and dominant taxa, see the Technical Appendix.

One of the uses of the IBI is to detect differences in individual metrics and determine impacts using additional information such as habitat, chemistry, and land use (Simon and Lyons 1995). Additionally, examining the composition and function of the community supplements the score and provides insight into the direct effects of environmental change and decline (Pederson & Perkins 1986).

5.4.2 Changes in Community Structure and Function

A shift in functional feeding group composition is noted in the test areas of all SPAs and coincides with development activities (see Technical Appendix for more in-depth analyses of these shifts). The shift from sensitive and specialized feeders, such as *shredders*, to generalist and more tolerant groups, such as *collectors* and *filterers*, are characteristic of disturbed streams that have been altered by urbanization processes. Similarly, a dominance of pollution-tolerant and less sensitive Chironomidae (true flies in the midge family) seen in the SPAs is frequently observed at disturbed sites like those in altered landscapes (Pedersen and Perkins 1986; Jones and Clark 1987; Moore and Palmer 2005; Diana et al. 2006).

This suggests that habitat, as well as food quality and availability, changed in these areas as a result of development activities, thereby negatively impacting the benthic fauna. Good quality habitat (such as stable and vegetated banks, wide, sinuous stream channels with coarse substrates, and ample and diverse cover and substrate) is associated with a diverse biological community. Conversely, unvegetated and eroding banks and deep channels with predominantly fine substrates are associated with poor biology (Pedersen and Perkins 1986; Jones and Clark 1987; Heitke et al. 2006; Moerke and Lamberti 2006).

Changes in community feeding structure and function were most obvious in the Clarksburg and Piney Branch SPAs, particularly with the dominance of more tolerant collectors and Chironomidae. Clarksburg and Piney Branch both underwent high-density, rapid development, but differ in that Clarksburg is undergoing development from a predominantly rural landscape while Piney Branch had previous high-density developments exerting *legacy effects*. Legacy effects from urbanization, agriculture, and other human impacts produce different, and generally degraded, biological assemblages from those in undisturbed systems (Wang et al. 2006). The recent development in the Clarksburg Newcut Road and Town Center neighborhoods currently has exposed and unconverted land, shifting biological community structure and function and limiting recovery at this time.

The level of disturbance in each SPA during development periods was an important influence on benthic community structure and function. The Upper Paint Branch and Upper Rock Creek SPA stream conditions and biological communities in areas undergoing development did not differ considerably from the control areas. For Upper Paint Branch, it appears that the 8% impervious cap restricting the amount and impacts of development, sediment and erosion controls, stormwater management, and the relatively short time to complete development (from 2003 to 2006) have limited some impacts to these areas.

In Upper Rock Creek, the phasing of development in addition to the 8% impervious cap has deterred construction impacts to the stream at this time, although it is relatively early in the development process. Changes to biological community structure and function generally take more than a year to materialize and construction has only just begun in 2007.

5.4.3 Future Stream Conditions and Potential for Recovery

How Much Will SPA Streams Recover After Development is Completed?

The Upper Paint Branch SPA streams are very likely to recover to near pre-construction conditions. It is uncertain whether a full recovery is possible. It appears that the 8% impervious cap restricting the amount and impacts of development, the sediment and erosion controls, stormwater management, and the relatively short time to complete development (from 2003 to 2006), have limited impacts to these streams.

The frequent, intense, and ongoing disturbances through the development period in the Clarksburg Master Plan SPA Town Center and Newcut Road areas may have impaired the ability of the benthic communities to fully recover to near pre-construction conditions.

The level of recovery and the direct influence of SWM BMPs (described to be "state-of-the-art" designs at the time) are unclear at this time. The ability of SWM BMPs to minimize impacts to streams cannot be considered separately from the development process. SWM is a component of the whole; the entire development process must be considered in its ability to minimize stream impacts.

The changes to the structure and function of the benthic macroinvertebrate community are reflected in the declining stream condition scores. The frequent, intense, and ongoing disturbances through the construction period, particularly in the Clarksburg Town Center and Newcut Road areas, may have impacted the ability of the benthic communities to recover (Moore and Palmer 2005) to near pre-construction conditions. Disruption to the natural system through the conversion of rural land use to urban land use may prevent a full recovery to pre-construction conditions (Konrad and Booth 2005; Wang et al. 2006). However, some improvement to habitat, and thereby benthic communities, is expected upon conversion to SWM.

If sensitive organisms are no longer present or if the habitat no longer supports these more sensitive taxa, the stream condition may not be able to fully improve.

Stream communities demonstrate some ability to recover following the flushing of deposited materials (Jones and Clark

1987). Recovery of benthic macroinvertebrates is expected as the pace of new construction slows, and areas are converted to SWM (Miltner et al. 2004). However, the level of recovery and the influence of BMPs are unclear at this time. Some findings indicate that large-scale and long-term disturbances in a watershed limit the recovery of stream communities for many decades (Harding et al. 1998) and that the impacts to the form and function of the aquatic systems occur rapidly and are very difficult to avoid or correct (Booth and Jackson 1997).

Although promising, the more stringent stormwater regulations and BMPs such as those utilized by the County have not been in place long enough to test whether they will minimize loss of aquatic life through development and build out. In addition to protecting streams by managing adjacent land use (e.g. leaving riparian zones intact, floodplains under-developed, and adjusting for potential hydrological impacts; described in Miltner et al. (2004)), it may be necessary to preserve entire watersheds, not just fragments or pieces of them (Harding et al. 1998).

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6. Conclusions

6.1 BMP Monitoring

BMP monitoring has demonstrated that the redundant features used in reducing stormwater runoff and decreasing pollutant loadings has been more effective than the use of individual structures. BMP feature placement in the treatment train is also an important consideration in optimizing BMP performance and mitigating impacts to receiving streams. Since the inception of the SPA program, DPS has consistently refined BMP design plans and reduced the size of the area draining to individual structures to improve pollutant removal efficiency and mitigate development impacts.

Measuring changes to stream geometry, habitat, and chemistry, and ultimately the biological community, must be examined as indicators of BMP effectiveness in protecting water quality. With these factors in mind, great care needs to be taken, not just when examining the County's results alone, but when trying to make comparisons between BMPs employed locally and nationally.

The current development process can transform the landscape and alter natural processes. The evolution of development in Clarksburg, from an undeveloped, rural environment to a dense suburban/urban environment, makes it a perfect test site to evaluate the ability of structural BMPs to protect water quality.

Thus far, results show that BMPs are performing as expected. However, the efficiency of the BMPs is not correlating to the health of the stream based on its biological integrity. Where once it was thought by some that reliance on engineered BMPs would be sufficient to minimize development impacts to stream conditions, it is becoming increasingly apparent that SWM BMPs alone, even when redundant, cannot provide all the solutions for minimizing impacts to streams and protecting water quality.

Many of the streams in the SPAs are small headwater streams that are extremely sensitive to changes in the surrounding soils, drainage features, groundwater recharge and diffuse rainfall infiltration. These changes become accentuated as the landscape alterations required for roads, utilities, lot grades, storm drains and other infrastructure increase due to approved densities. Imperviousness levels resulting from the approved densities can be important indicators of the degree of impacts that will result to the headwater streams. There are insufficient data at this point in the development process to evaluate if the watershed will recover from the negative effects documented during construction.

6.2 Stream Characteristics

The Newcut Road Neighborhood development has been monitored by the Clarksburg Monitoring Partnership since 2002. BMPs used in this area were state-of-the-art at the time and designed to meet the current state SWM design manual.

In this portion of the Newcut Road:

- Natural drainage patterns have almost been eliminated;

- Overall topography, natural drainage patterns, and natural infiltration have been altered due to the cut and fill requirements necessary to meet the development requirements of these neighborhoods; and,

- Most of the stormwater runoff is now diverted into stormwater inlets and drains rather than infiltrating into the ground over a wide area as it did before.

The greater the impervious surfaces that cover a watershed, the smaller the amount of precipitation that infiltrates into the groundwater system and the more runoff enters the streams directly. The effects of impervious surface first become evident through the grading and compaction activities that currently occur throughout the site as a result of development. Naturally pervious soils and a diffuse infiltration system are altered and/or lost through the cut and fill requirements currently being followed to develop a property. These changes occur beyond the actual final paved surfaces, limiting the effectiveness of seemingly pervious area, adding to the need to adequately remediate areas where infiltration is desired.

6.3 Biological Stream Monitoring

Stream conditions changed little in the SPAs from 2007 to 2008. Out of forty-nine stations monitored in 2008 for this report, five stations had improved stream conditions from 2007. Forty-four stations (90%) had no change in stream conditions from 2007. Two stations in Clarksburg improved from *fair* to *good;* one station within the lower Town Center Tributary and the other station located within a tributary of Great Seneca Wildcat Branch. Two stations in the Piney Branch SPA improved from *poor* to *fair.* In the Upper Paint Branch SPA one station improved from *fair* to *good*.

Stream conditions in Ten Mile Creek remain in *good* condition. Brown trout – indicators of good water quality and one of the most sensitive species to disturbance – were again found in Ten Mile Creek. However, stream conditions have declined and remain *fair* in the eastern headwaters of Ten Mile Creek (mostly east of I-270). This area receives runoff from some of the Clarksburg Detention Center, I-270, and portions of other Clarksburg developments under construction. Current imperviousness is 12% and high conductivity readings were found throughout the drainage area. As a result of the long term biological stream monitoring program, the sensitivity of the high quality Ten Mile Creek to impacts is apparent.

The Upper Paint Branch SPA streams are likely to recover to near pre-construction conditions. There are a number of factors that influence recovery including: the 8% impervious cap; sediment and erosion controls; stormwater management; and the short time to complete development (2003 to 2006). Additional data collection and analysis will help determine the specific level of recovery and the influence of SWM BMPs (described to be “state-of-the-art” designs at the time). The ability of SWM BMPs to minimize impacts to streams cannot be considered separately from the development process. SWM is a component of the whole; the entire development process must be considered in its ability to minimize stream impacts.

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7. Recommendations

A number of recommendations were provided in the 2007 SPA report. Follow up on these recommendations has started. The State Stormwater Management Act of 2007 will soon require all jurisdictions to implement Environmental Site Design (ESD) for all new development to the extent practicable. It will also require modification to all relevant codes and regulations as needed to facilitate the application of ESD.

The use of ESD may further mitigate watershed-scale environmental impacts from development compared with more traditional strategies depending on the extent of development already in the watershed and on the determination of maximum extent practicable. It is anticipated that some of the code and regulatory recommendations in the 2007 and 2008 SPA reports will be proposed during that time. Others will be proposed during the update to the sediment and erosion control regulations described in Section 7.3

7.1 Water Quality Review Process

The SPA water quality plan and development review process is being evaluated to ensure that stormwater management and full protection of environmental buffers and other environmentally-sensitive areas are given a higher priority in land development projects in the SPAs. DEP, DPS, and M-NCPPC are in discussion on how to ensure that SWM facilities are sited before, or at least concurrently with, the other utilities and infrastructure – not after roads and other major infrastructure are in place. This process will become more integral to the development process as the new regulations for the Stormwater Act of 2007 are implemented.

7.2 BMP Water Quality Monitoring Process

Code changes are being considered that will provide developers with an option to have DEP perform the monitoring by paying a BMP monitoring fee. This would allow for more consistency and reduce some of the problems encountered with monitoring. These code changes will be implemented as part of the overall changes to Chapter 19 of the County Code needed for the Stormwater Act of 2007.

7.3 Sediment and Erosion Control Improvements

MDE is currently conducting a complete re-write of the state sediment and erosion control regulations. Changes under consideration as part of that update include faster conversion from S&EC to SWM, stricter phasing stages of construction to allow greater focus on soil stabilization, limiting the acres of exposed soils, stricter utility S&EC, and limiting of cut and fill activities to retain natural drainage patterns. DPS is representing Montgomery County on the statewide workgroup. Montgomery County has traditionally been the leader in progressive sediment and erosion control regulations and expects that it will exceed requirements of the new MDE regulations.

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9. Glossary

Base flow – The portion of the stream discharge that is derived from natural storage (i.e., groundwater outflow and the draining of large lakes and swamps or other sources outside the net rainfall that create surface runoff); discharge sustained in a stream channel, not a result of direct runoff, and without the effects of regulation, diversion, or other works of man. Also called sustaining, normal, ordinary, or groundwater flow.

Before-After, Control-Impact (BACI) Design – An experimental design used to assess environmental impacts. Data is collected Before and After a change and the data is compared between Control and Impacted stations. BACI design is used to account for extraneous factors (such as natural variation). In the Clarksburg SPA, test areas are monitored before and after development and compared to an area where no activity is to occur (Sopers Branch control) and an area where build out is complete and older SWM controls are in place (Germantown/Crystal Rock control).

Benthic macroinvertebrate – Bottom-dwelling aquatic animals lacking a backbone that are visible to the naked eye. This group of organisms includes aquatic insects, worms, crustaceans, and mollusks in streams, rivers, lakes, estuaries, and oceans.

Best Management Practices (BMPs) – Technique, measure or structural control used to manage pollution or other detrimental impacts to a watershed or wetland.

Biological integrity – The condition of the biological communities of a water body based on a comparison to the biological communities in a reference water body that represents the best conditions to be expected for that region.

Bioretention structure/area/facility – A stormwater best management practice (BMP) that uses physical, chemical and biological properties of soils, microbes, and plants to filter pollutants from stormwater runoff. Some reduction in stormwater velocity can also be achieved. Bioretention cells are designed to collect, and store stormwater runoff from on- lot impervious areas such as parking lots and allow it to infiltrate into soils. Cells can be incorporated into median strips, parking lot islands and swales.

Catchment – The area of land draining to a BMP or by a stream or stream system.

Channel protection volume (Cpv) – A design criteria which requires 24 hour detention of the one year post-developed, 24 hour storm event for the control of stream channel erosion.
http://www.mde.state.md.us/assets/document/sedimentstormwater/Glossary.pdf

Collectors – Organisms that consume fine or dissolved pieces of organic matter (e.g., leaf fragments or other material on the stream bottom).
http://www.epa.gov/bioindicators/html/invertclass.html

Cut and fill – Process of earth moving by excavating part of an area and using the excavated material for adjacent embankments or fill areas.

Effluent – (Outflow) Stormwater that leaves the outfall of a S&EC or SWM BMP or sewer.

Embeddedness – The extent that large stream substrate (i.e. boulders, cobbles, gravel) is surrounded by or covered by fine sediment (sands, silts, and clays).

Environmental Overlay Zone – A zone or district created to conserve natural resources or promote certain types of development. The environmental overlay zones in SPAs aim to protect water quality and quantity and biodiversity. This is accomplished by regulating the amount and location of impervious surfaces in order to maintain groundwater levels, control erosion and allow the ground to filter water naturally, thereby minimizing the temperature and volume of stormwater runoff.

Environmentally sensitive areas – Refers to areas having beneficial features to the natural environment, including but not limited to: steep slopes; habitat for Federal and/or State rare, threatened, and endangered species; 100-year ultimate floodplains; streams; seeps; springs; wetlands, and their buffers: priority forest stands; and other natural features in need of protection.

Environmental Site Design (ESD) – A stormwater management strategy aimed at maintaining or restoring the natural hydrologic functions of a site to achieve natural resource protection objectives and fulfill environmental regulatory requirements. Under this premise, stormwater discharges are to be controlled to the maximum extent practicable and nonstructural BMPs and other better site design techniques must be implemented.

Ephemeral stream – A stream channel located above the water table and thereby only carries water during and immediately after periods of precipitation or snowmelt.

Evapotransporation – The loss of water by evaporation from water surfaces and by transpiration from plants.

Filterers – Organisms that are suspension feeders or filter dissolved particles from the water column; a subcomponent of the group of organisms known as collectors.
http://www.epa.gov/bioiweb1/html/invertclass.html

First flush – The first inch of rain over the impervious area creating stormwater with the highest pollutant loading.

Flow splitter – An engineered, hydraulic structure designed to divert a percentage of storm flow to a BMP located out of the primary channel, or to direct stormwater to a parallel pipe system or to bypass a portion of base flow around a BMP.

Flow-weighted composite sample – A mixed or combined sample that is formed by combining a series of individual and discrete samples at specific intervals and characterized by the flow rate of the discharge. This sampling method characterizes the entire storm event and the measured flow is used to calculate the loading of pollutants in the stormwater sample.

Forebay – Storage space located near a stormwater BMP inlet that serves to trap incoming coarse sediments before they accumulate in the main treatment area.
http://www.mde.state.md.us/assets/document/sedimentstormwater/Glossary.pdf

Functional feeding groups – designations that characterize how organisms in the community obtain food.

Geomorphology – See “Stream morphology”.

Grab sample – A single sample of stormwater representing the concentration of pollutants at a discrete point in time. This method of sampling does not represent an entire storm event.

Headwater streams – These small streams are the origins of larger streams and rivers and the place from which the water in the downstream water bodies originates. The health of the larger systems depends upon the condition of the headwater areas. Headwater streams are small and typically fed by groundwater, however some may be ephemeral / intermittent, drying seasonally or just under drought conditions. Because of their small size and variability, they tend not to support a well-balanced fish community.

Home range – The area in which an animal carries out its normal activities.

Hydrodynamic device – See “Hydrodynamic structure”.

Hydrodynamic structure – (also Hydrodynamic device or separator) is a class of SWM BMPs that treat stormwater by slowing flow to remove sediment and other pollutants. Depending on the device, treatment may be accomplished by swirling the water or through settling and indirect filtration. Due to these processes, hydrodynamic structures are most effective at treating heavy particulates (such as suspended solids) or “floatables” (such as oil). They are often used as pre-treatment in SPAs and can be either proprietary (trademarked/patented by a corporation) or non-proprietary.

Hydrograph – A graph showing variation in stage (depth), discharge, flow, or velocity over time in a stream of water.

Hydrology – The study of water and its occurrence, dynamics, and function in the environment.

Imperviousness (Impervious surface or area) – Impervious surfaces are those that are impenetrable to rainwater, snow melt, and runoff and prevent the natural infiltration of water into the soil. Impervious surfaces include parking lots, roads, rooftops, and sidewalks as well as soils compacted during the development process.

Index of biotic integrity (IBI) – A measurement of the aquatic community's structure and function within Special Protection Areas as compared to the aquatic community inhabiting the least impaired reference streams within a specific region.

Infiltration – The movement of water through the ground surface into the soil. Also the technique of applying large volumes of waster or stormwater to land to penetrate the surface and percolate through the underlying soil.

Infiltration trench – A SWM BMP designed to manage stormwater quantity and quality by allowing stormwater to infiltrate through permeable soils into the groundwater. Generally, it is a shallow excavated trench filled with gravel or a similar material and lined with filter fabric that treats water as it percolates into the groundwater. Pollutants are filtered out as runoff infiltrates the surrounding soils. Infiltration trenches also provide groundwater recharge and preserve base flow in nearby streams.

Influent – (Inflow) stormwater runoff flowing into a S&EC or SWM BMP or sewer.

Irreducible level/concentration – A limit to how much pollutant removal can be achieved; it is a level in which sediment and nutrient concentrations exist at such low levels that they cannot be reduced further, regardless of how much more surface area, treatment volume, or additional treatment types are provided.

Land use – The way in which land is zoned, delineated, and used. Categories include urban (open space and low, medium, and high density), forest (including wetlands), agriculture (pasture/hay, cultivated crops), open water, and other (i.e. barren land, unconsolidated shore).

Legacy Effect – Residual impacts to an environmental system remaining from previous land use practices.

Limit of Disturbance – Boundary containing all development and construction activities.

Metrics – Attribute or measurable characteristics of a biological assemblage that provides reliable and relevant signals about the effects of environmental and anthropogenic stresses.

Oil-grit separator – also known as a water quality inlet (WQI), consist of a series of chambers that promote sedimentation of coarse materials and separation of free oil (as opposed to emulsified or dissolved oil) from storm water. WQIs typically capture only the first portion of runoff for treatment and are generally used for pretreatment before discharging to other best management practices (BMPs). http://www.epa.gov/owm/mtb/wtrqlty.pdf

One-year (1-year) storm – A storm that has a recurrence interval (or frequency) of one year orstatistically has a 100% chance on average of occurring in a given year; approximately 2.6 inches rainfall in 24 hours.

Outfall – The end/outlet of a structural BMP, drain, or sewer.

Paired catchment (watershed) design – A study design that pairs control and test drainage areas along similar natural characteristics. See "Before-After, Control-Impact (BACI) Design"

Pioneer species – The first species or groups of species to colonize or re-colonize a barren or disturbed environment. A high number of these types of species typically indicates a stressed environment or one that is lacking features necessary for more specialized or sensitive species, thereby reflecting lower biotic or biological integrity.

Pollutant – Generally, any substance introduced into the environment that adversely impacts a natural resource or the health of humans, animals, plants, or ecosystems.

Recharge volume (Rev) –The requirement to have a specific volume of stormwater runoff or water quality volume (WQv) recharged into the groundwater in order to reverse the impacts of paved surfaces on groundwater infiltration. The recharge volume is based on the hydrologic soil groups and the amount of impervious area.

Regulatory weir – a device acting like an obstruction (such as a wall or plate) that controls the flow of stormwater in a treatment train.

Riparian/ Riparian zone – An area of land and vegetation adjacent to a stream that has a direct influence on the stream. This includes woodlands, vegetation, and floodplains.

Sediment and Erosion Control (S&EC) – Sediment and Erosion Controls are BMPs installed prior to construction and land disturbance activities to capture and treat sediment-laden runoff. Examples utilized in SPAs include supersilt fences and sediment basins outfitted with additional treatment features.

Sedimentation – Sedimentation is the process of sediment loads entering the stream system and covering the stream bed. Excessive loadings of fine sediment degrades and eliminates riffle and pool habitats available for benthic macroinvertebrates, fish, and stream salamanders. Excessive sediment loads can smother these organisms and their eggs. The movement of sediment can actually scour the stream bottom, accelerate erosion, and diminish bank stability.

Seep – Water feature fed exclusively by groundwater. Seeps typically do not flow.

Shredders – Organisms that consume coarse organic matter such as leaves. http://www.epa.gov/bioindicators/html/invertclass.html

Spring – Water feature fed by groundwater that flows intermittently or constantly.

Stormwater Management (SWM) – Stormwater Management is a BMP utilized on properties after construction is complete to control the quantity and quality of stormwater runoff. Stormwater Management in the SPAs includes treating the first inch of rain over the impervious/developed surface (also known as the "first flush") as quality control and controls stormwater flows by storing the one-year, 24 hour storm (about 2.6 inches of rain). Quality treatment is aimed at minimizing pollutant loadings of receiving streams whereas quantity control functions primarily as maintaining natural stream flows, groundwater infiltration, and bank stability.

Stream flashiness – The stream flow response to storms. Increased stream flashiness means stream flow and water elevations increase (peak) and decrease rapidly in response to storm events. This increased response can erode stream channels and impair stream habitat and aquatic communities.

Stream morphology – The study of the changes to stream channel form, shape, structure, and area over time.

Taxa – The plural form of taxon. A category or group of organisms.

Tolerance values – A rating assigned to an organism that represents its ability to tolerate various environmental stressors (such as low dissolved oxygen levels, high amounts of siltation or salinity, or varying amounts of toxic chemicals).

Topography The physical features of the land's surface area including elevations and positions of natural and man-made features.

Total Kjeldahl nitrogen (TKN) – The sum-total of organic and ammonia nitrogen in a sample, determined by the Kjeldahl method.

Total Petroleum Hydrocarbon (TPH) – Measure of the concentration or mass of petroleum hydrocarbon constituents present in a soil or water sample. TPH is a family of chemical compounds (exclusively hyrdrogen and carbon)found in petroleum products that originally come from crude oil. Some chemicals that may be found in TPH are gasoline and fuel components, mineral oils, hexane, benzene, toluene and fluorene.

Total Suspended Solids (TSS) – The weight of particles that are suspended in water. Suspended solids in the water clog the gills of fish, invertebrates, and larval amphibians, reduce the ability of light to penetrate the water column, and decrease stream habitat availability and quality when they settle on the stream substrate. Suspended solids also bind to metals and other contaminants which can be toxic in aquatic systems.

Transfer of Development Rights (TDR) – A method for protecting land by transferring the "rights to develop" from one area and giving them to another. The TDR program in Montgomery County allows developers to increase residential density in designated areas outside of the Agricultural Reserve to compensate farmers for the land equity lost through the down-zoning that created the Ag. Reserve.

Trash rack – Grill, grate or other device installed at the intake of a channel, pipe, drain or spillway for the purpose of preventing oversized debris from entering the structure. http://www.mde.state.md.us/assets/document/sedimentstormwater/Glossary.pdf

Vegetated swale – A SWM BMP designed to trap particulate pollutants (suspended solids and trace metals), promote infiltration, and reduce the flow velocity of stormwater runoff. It is a broad, shallow channel with vegetation covering the side slopes, and bottom. They can be natural or man-made. Vegetated swales can serve as part of a storm water drainage system and can replace curbs, gutters and storm sewer systems. Therefore, swales are best suited for residential, industrial, and commercial areas with low flow and smaller populations. http://www.epa.gov/owm/mtb/vegswale.pdf

Water Quality Inventory – All persons proposing to disturb land within an SPA, except as provided by law, must submit, for review and approval, a water quality inventory which covers any portion of the project located within the SPA. The inventory includes a stormwater management concept plan, a sediment control concept plan, documentation of impervious areas, additional documentation to show avoidance, minimization, or proposed mitigation for impacts on environmentally sensitive areas, and on priority forest conservation areas as specified in the Planning Board’s Environmental Guidelines, and rationale for any proposed encroachment on said areas (per Montgomery County Regulation on Water Quality Review for Development in Designated Special Protection Areas).

Water Quality Volume (WQv) – The volume needed to capture and treat 90% of the average annual stormwater runoff volume equal to 1 inch times the volumetric runoff coefficient (Rv) times the site area. http://www.mde.state.md.us/assets/document/sedimentstormwater/Glossary.pdf

Water Year Reports – The U.S. Geological Survey "water year" in reports that deal with surface-water supply is defined as the 12-month period October 1, for any given year through September 30, of the following year. The water year is designated by the calendar year in which it ends and which includes 9 of the 12 months. Thus, the year ending September 30, 1999 is called the "1999" water year. http://water.usgs.gov/nwc/explain_data.html

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- George Mason University
- United States Environmental Protection Agency (U.S. EPA)
  Landscape Ecology Branch, Research Triangle Park, NC
- U.S. EPA National Risk Management Research Laboratory, Cincinnati, OH
- U.S. EPA Office of Research and Development, Atlanta, GA
- U.S. EPA Environmental Science Center, Ft. Meade, MD

RELATED DOCUMENTS:

- SPA Annual Report, 2007
- SPA Annual Report, 2006
- SPA Annual Report, 2005
- SPA Annual Report, 2004
- SPA Annual Report, 2003
- SPA Annual Report, 2002
- SPA Annual Report, 2001
- SPA Annual Report, 2000
- SPA Annual Report, 1999
- SPA Annual Report, 1998
- Clarksburg Conservation Plan
- Piney Branch Conservation Plan
- Upper Paint Branch Conservation Plan

All of the documents cited above are available online in PDF format on our website:
http://www.montgomerycountymd.gov/deptmpl.asp?url=/content/dep/SPA/home.asp
In addition, the Department of Environmental Protection maintains an extensive collection of annual, technical, and general reports, public information factsheets, and related publications. Many are available in both PDF and HTML format, and in some cases, print copies of documents are available. Please contact us for more information.

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